2015

# The distribution and nest survival of Giant Canada Geese breeding in Iowa

Brenna N. Towery
*Iowa State University*

# The distribution and nest survival of Giant Canada Geese breeding in Iowa

by

**Brenna N. Towery**

A thesis submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Wildlife Ecology

Program of Study Committee:
Robert W. Klaver, Major Professor
Stephen J. Dinsmore
Diane M. Debinski

Iowa State University

Ames, Iowa

2015

# TABLE OF CONTENTS

# LIST OF TABLES

## LIST OF FIGURES

## ACKNOWLEDGEMENTS

First and foremost, I would like to thank my family and friends for all of your support and encouragement. Eric – you somehow know me better than I know myself and without you I don't know how I would have managed the stresses of this crazy life. Becca – thanks for being my "mentor" but, more importantly, thanks for being my friend. Your friendship and wisdom were invaluable during this entire process.

I would like to thank my advisor, Bob Klaver, for taking me on as his first student. Thank you for your guidance and support, as well as your patience. Thank you to S. J. Dinsmore and D. M. Debinski for serving on my committee and providing valuable guidance and knowledge. I've learned so much from all of you.

Philip Dixon – I truly appreciate all of your guidance with regards to modeling. I am lucky to have had you as a resource.

Thank you to the Iowa Department of Natural Resources (DNR) and the United States Geological Survey for funding this project. This project was funded by the Iowa DNR Fish and Wildlife Trust Fund Contract CRWB0046-8340-WSUCH and Cooperative Agreement Number G12AC20381 from the United States Geological Survey. Thank you also to Iowa State University for providing me with a teaching assistantship.

Guy Zenner – thank you for your guidance and mentorship. Most importantly, thank you for working with me for hours on end while we poured over every detail of your survey data. I truly enjoyed spending time with you and getting to know you and your family. Orrin Jones – you've been an incredible mentor and I can't thank you enough for your endless support. Thank you to the Iowa DNR fisheries and wildlife management units in Clear Lake and Ventura for all of you support as well.

Thank you to P. Bartelt, P. Eyheralde, J. Godwin, S. Handrigan, O. Jones, K. Murphy, R. Reeves, and G. Zenner for your assistance with field work. Jessica – I couldn’t have asked for a better field technician. Thanks to Deb Sharar for allowing me to stay in her wonderful lakeside cabin during the field season. You all made my life so much easier!

Bill Clark – I’m very lucky to have gotten to know you before your retirement from Iowa State and I’d like to thank you for your mentorship, not only with regard to graduate school, but for introducing me to the amazing world of turkey hunting! I’ll never forget the thrill of shooting my first turkey.

Last but not least, thank you to my fellow graduate students. To my office mates in particular, I apologize for any distractions I may have caused but thank you for keeping me sane.

# CHAPTER 1. GENERAL INTRODUCTION

## Background

The giant Canada goose (*Branta canadensis maxima*) is a true conservation success story. The species was extirpated from most of its range in the early 1900s due to decades of unregulated hunting and habitat loss (Hanson 1997). Giant Canada geese (hereafter Canada geese) and their eggs were overharvested for commercial trade (Bishop 1978, Hanson 1997), and essential wetland habitat was drained for agricultural purposes throughout the central United States resulting in a drastic decline in the population (Schrader 1955). Canada geese weren't alone in the battle against settlers and the decline of many other bird species resulted in an international treaty to protect an extensive list of migratory birds (Finet 1996). The Migratory Bird Treaty Act of 1918 (16 U.S.C. 703-712) was one of the first steps toward recovery of the Canada goose population (Fjetland 2000). A provision of the 1918 statute permitted States to implement harvest regulations for species that had been hunted historically (16 U.S.C. 708). This, however, required a thorough understanding of the natural history, population dynamics, and distribution of these species.

Canada geese were thought to be extinct by the 1950s until small remnant populations were discovered overwintering in Minnesota in the 1960s (Hanson 1997). This inspired wildlife biologists to trap, breed, and hand-rear Canada geese for release throughout its historic range (Lee at al. 1984). Headed by Forrest Lee (a.k.a Father Goose), the Northern Prairie Wildlife Research Center initiated a Canada goose restoration program that was responsible for the successful recovery of the species (Lee et al. 1984). Iowa's participation in the recovery program began in 1964 (Bishop and Howing 1972) and involved holding flocks of flightless adult geese at 15 wetland areas across the state for the purpose of repopulating the surrounding wetland habitat with their free-flying offspring. The Iowa Dept. of Natural Resources (DNR) also released flightless goslings at 28 different wetland sites to speed the population restoration process, and by 1993 Canada geese were nesting in every county in Iowa (Zenner and LaGrange 1998).

Canada geese are one of the most commonly harvested species of waterfowl in the Mississippi Flyway, second only to mallards (*Anas platyrhynchos*) in most states (Leafloor et al. 2004). States with resident populations of these birds, such as Iowa, require sound science-based management and monitoring protocols. Breeding populations are monitored in Iowa using a stratified random sampling method to select square-mile sections to be surveyed by helicopter (O. Jones, Iowa DNR, unpublished report). Geese counted in the sample of sections are extrapolated to produce a statistically valid population estimate for the state. Precise estimates require that the universe of survey plots be accurately stratified. Also, reliable estimates of nest survival allow the DNR to evaluate available nesting habitats and determine what habitat management techniques may be necessary to enhance production (Miller and Johnson 1978). Updated measurements of these elements are essential to develop and evaluate Canada goose management strategies.

## Goals and Objectives

The overall goal of this study was to improve the estimates of the Canada goose breeding population in Iowa by updating and improving the survey stratification process. In addition, I evaluated nest survival in various habitats to provide updated productivity data. The specific objectives were as follows:

1. Develop a model to predict Canada goose breeding pair densities using National Wetlands Inventory and historic breeding population survey data.

2. Investigate Canada goose nest densities and nest success on extant islands at Rice Lake Wildlife Management Area (WMA) and compare these estimates to a study conducted during 1988–91.

3. Determine how available nesting habitat and other factors influence Canada goose nest survival at rural wetlands in north-central Iowa.

## Thesis Organization

This thesis follows the journal paper format and each chapter is formatted as such. Chapter 1 provides a general introduction to the thesis. Chapters 2 through 4 address the research objectives outlined above. Specifically, Chapter 2 is a paper that describes a methodology to modeling breeding pair densities of Canada geese, Chapter 3 is a paper comparing Canada goose nest success and nest densities on islands to estimates reported by a previous study of a WMA that historically produced high densities of geese, and Chapter 4 is a paper on Canada goose nest survival at rural wetland sites with different nesting habitats. Chapter 5 summarizes the general conclusions of the three journal papers that comprise this thesis. Manuscript authors contributed to the research design, data analyses, and writing/editing of these papers.

## Literature Cited

Bishop, R. A., and R. G. Howing. 1972. Re-establishment of the giant Canada goose in Iowa. Proceedings of the Iowa Academy of Science 79:14–16.

Bishop, R. A. 1978. Giant Canada geese in Iowa. Iowa Conservationist 37:5–12.

Finet, S. 1996. Habitat protection and the Migratory Bird Treaty Act. Tulane Environmental Law Journal 10.

Fjetland, C. A. 2000. Possibilities for Expansion of the Migratory Bird Treaty Act for the Protection of Migratory Birds. Natural Resources Journal 40:47–68.

Hanson H. C. 1997. The giant Canada goose. Revised edition. Southern Illinois University Press: Carbondale, Illinois, USA.

Leafloor, J. O., K. F. Abraham, F. D. Caswell, K. E. Gamble, R. N. Helm, D. D. Humburg, J. S. Lawrence, D. R. Luukkonen, R. D. Pritchert, E. L. Warr, G. G. Zenner. 2004. Canada goose management in the Mississippi Flyway. Pages 22–36 *in* Moser, T. J., R. D. Lien, K. C. Vercauteren, K. F. Abraham, D. E. Andersen, J. G. Bruggink, J. M. Coluccy, D. A. Graber, J. O. Leafloor, D. R. Lukkonen, R. E. Trost, editors. Proceedings of the 2003 International Canada Goose Symposium, 19–21 March 2003, Madison, Wisconsin, USA.

Lee, F. B., C. H. Schroeder, T. L. Kuck, and L. Schoonover. 1984. Rearing and restoring giant Canada geese in the Dakotas. North Dakota Game and Fish Department: Bismarck, North Dakota, USA.

Migratory Bird Treaty Act. (16). United States Code 703-712. 13 July 1918.

Miller, H. W., and D. H. Johnson. 1978. Interpreting the results of nesting studies. Journal of Wildlife Management 42:471–476.

Schrader, T. A. 1955. Waterfowl and the potholes of the north central states, in The yearbook of agriculture 1955: Washington, D.C., U.S. Department of Agriculture, 84th Congress, 1st Session, House Document no. 32:596–604.

Zenner, G. G., and T. G. LaGrange. 1998. Giant Canada geese in Iowa: restoration, management, and distribution. Pages 303–309 *in* D. H. Rusch, M. D. Samuel, D. D. Humburg, and B. D. Sullivan, eds. Biology and management of Canada geese. Proceedings of the International Canada Goose Symposium, Milwaukee, Wisconsin, USA.

# CHAPTER 2: MODELING CANADA GOOSE HABITAT USE TO PREDICT BREEDING PAIR DENSITIES

A paper to be submitted to *Journal of Fish and Wildlife Management*

Brenna N. Towery[1], Robert W. Klaver[2], and Guy G. Zenner[3]

[1]Department of Natural Resource Ecology and Management, Iowa State University, Ames, IA 50011;

[2]U.S. Geological Survey, Iowa Cooperative Fish and Wildlife Research Unit, Ames, IA 50011;

[3]Iowa Department of Natural Resources, Clear Lake, IA 50428

## Abstract

Effective management of Canada geese (*Branta canadensis*) requires precise population estimates. The key to precisely estimating the population in a region is to accurately stratify the universe of potential survey plots. Iowa's survey currently utilizes a stratification based on breeding pair densities predicted by ad hoc regression models and wetland data from the 1986 National Wetlands Inventory (NWI) database. Using five years of breeding population survey data and updated NWI data, we developed a statistical model that predicts breeding pair densities for each section in the state based on the number, size, and types of wetlands in the section. The inclusion of survey data in the model resulted in a more statistically valid stratification of survey plots for the Canada goose breeding population survey which will improve the precision of population estimates for Iowa. These methods are applicable to all Mississippi Flyway states and provinces and have the potential to improve Canada goose management in the flyway as a whole.

**Keywords** *Branta canadensis*, breeding population survey, breeding pair densities, Canada goose, Iowa, stratification, Mississippi Flyway, National Wetlands Inventory

## Introduction

Reliable population and production estimates are essential for waterfowl conservation and management (Schneider et al. 1994). Canada goose (*Branta canadensis*) management is especially important because they are one of the most heavily harvested waterfowl species in the Mississippi Flyway, second only to mallards (*Anas platyrhynchos*) in most states (Leafloor et al. 2004). Aerial surveys of the wintering grounds were initiated in the 1960s, but by the late 1980s expanding giant Canada goose populations were confounding population estimates of the other Canada goose subpopulations (Miss. Flyway Counc. Tech. Sect. Minutes, Nashville, Tenn., 22 February 1991). In the early 1990s, breeding population surveys were recognized as more precise and statistically rigorous methods of estimating these populations (Babcock et al. 1990; Trost et al. 1990). Population estimates are often produced by counting geese on a sample of plots or along selected transect lines during the breeding season and then extrapolating these observations to the rest of the survey region. Breeding population surveys are statistically rigorous because the sampling design, which usually involves stratification of plots or transects based on habitat differences or densities of geese on the breeding grounds, allows for variance estimation (Malecki et al. 1981; Leafloor et al. 2004).

Mississippi Flyway states and provinces have been developing and refining methods to conduct breeding population surveys since 1993 (Miss. Flyway Counc. Tech. Sect. Minutes, Marion, IL, 18 February 1992). Breeding population survey methods, however, remain highly variable among states and provinces. For example, Wisconsin, Michigan, and Manitoba survey Canada geese along transects selected by the U.S. Fish and Wildlife Service (USFWS) for the North American Waterfowl Breeding Population Survey. Alternatively, Minnesota surveys ¼ section plots, while Iowa and other states survey 2-$mi^2$ plots.

The key to precisely estimating the Canada goose breeding population is to accurately stratify the universe of survey plots. Iowa's sections were previously stratified three times during 1993–2005 (G. G. Zenner, Iowa DNR, unpublished data). The first stratification was based on potential breeding pair densities reported by DNR field biologists who were intimately familiar with the distribution of nesting geese in the counties they managed. By the late 1990s, the Canada goose population had expanded its range in Iowa prompting re-stratification of sections for the breeding population survey. Also, the 1986 National Wetlands Inventory (NWI) database for Iowa had recently come available enabling the use of this new wetland information to develop regression models to predict breeding pair densities for each section. Predictions were verified or corrected by DNR field biologists to improve accuracy of the stratification of the plots. Iowa's sections were stratified a third time in 2004 because extensive wetland restoration projects and new farm pond developments substantially altered wetland habitats on the landscape which resulted in imprecise Canada goose population estimates. Breeding pair numbers per section were predicted by using modified regression models that incorporated updated wetland information for about a third of Iowa. These predictions were also corrected by Iowa's field biologists. Unimpressed by the precision surrounding the resulting population estimates, the DNR's waterfowl biologist attempted to improve the stratification process by documenting the geese observed on each wetland in the surveyed sections for five years (2005–09) with the intention of incorporating these observations into predictive models (G. G. Zenner, Iowa DNR, personal communication).

We used the five years of observations, along with the most recent NWI data for Iowa, to develop statistically rigorous models to predict breeding pair densities. National Wetlands Inventory data were used to inform the models because we hypothesized that Canada goose breeding pair density and distribution are most likely a function of the number, size, and types of wetlands in a section. Breeding pair densities were predicted by (1) re-classifying the wetlands identified in the NWI to reduce the number of classifications to a more manageable number, (2) digitizing the goose observations from the aerial surveys (2005–09) and assigning pairs to the proper wetland type, (3) identifying the sections in Iowa with potential Canada goose nesting habitat based on the five years of breeding population survey data, (4) developing a regression model to predict the number of Canada goose breeding pairs in each section in Iowa, and (5) assigning sections to a stratum based on the predicted number of breeding pairs. Our approach to stratifying sections could be useful in other states and provinces in the Mississippi Flyway.

## Materials and Methods

### Survey data

Iowa's Canada goose breeding population survey is conducted annually in April using a helicopter to count Canada goose singles and pairs, with and without nests, on 165 2-mi$^2$ plots (n = 330 sections). A single goose is assumed to indicate a pair (Dzubin 1969) and the observed singles and pairs are combined to produce an estimate of indicated pairs per survey plot. The observed indicated pairs are expanded to produce an estimate of the breeding population for the state. Survey plots are paired square-mile sections which have been selected using a stratified random sampling method from strata defined by the number of breeding pairs predicted to be found in the section. Sections were sampled from four possible strata: (1) 1–2 pairs, (2) 3–6 pairs, (3) 7–12 pairs, and (4) >12 pairs. Also, survey plots were sampled from the PPR and the rest of the state separately due to historical differences in wetland characteristics and goose densities. There was a concern, at the time, that if the PPR was over represented in the survey, then the statewide goose population would be overestimated. Urban areas were included in the

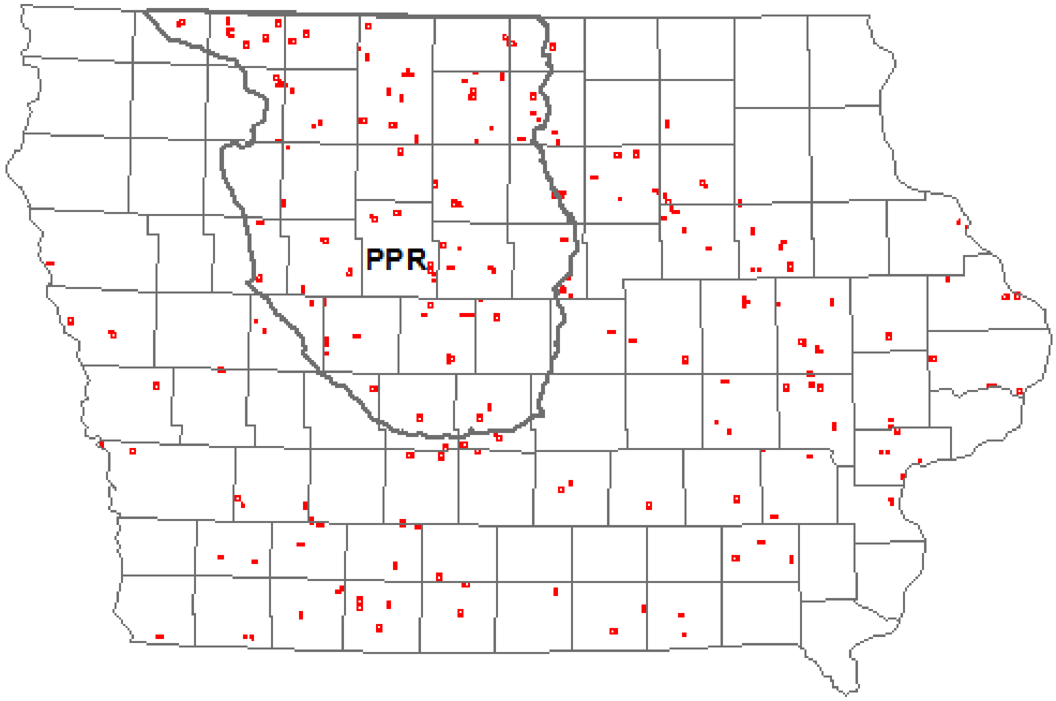



Figure 1. County map of Iowa designating the paired square-mile plots surveyed for Iowa's Canada goose breeding population survey, sampled from the Prairie Pothole Region (PPR) and the rest of the state during 2005–2009.

sampling universe but were not parsed out for the survey because all predictions had been corrected by local biologists, so sections with urban wetlands had been accurately stratified. Plots with elevated goose densities in urban areas were selected at a proportion similar to other high density plots. The selected 2-mi$^2$ plots lie within 71 of Iowa's 99 counties (Figure 1). We incorporated five consecutive years (2005–09) of survey data into a regression model to update predicted breeding pair densities for Iowa sections. During the 2005–09 surveys a maximum of 322 square-mile sections were surveyed due to time constraints or poor weather conditions. The observed goose numbers in the 2005–09 breeding population surveys were highly variable within strata. For example, during the 2005 survey a range of 0 to 11 pairs were observed in sections assigned to the 1–2 pair stratum, and a range of 0 to 37 pairs was observed in sections assigned to the 3–6 pair stratum. By incorporating survey data into the regression model, we hoped to reduce this within-stratum variance.

**National Wetlands Inventory reclassification**

Wetland data from the National Wetlands Inventory (NWI) were most recently updated for Iowa in 2002 and became available digitally in 2012. We manipulated the NWI polygons in ArcMap (ESRI, Redlands, CA) to compile a dataset of wetland types, area per type, and total wetland area in each section. The NWI uses an alpha-numeric wetland classification system developed by Cowardin et al. (1979), which classifies each wetland basin based on water flow, substrate composition, and dominant vegetation, among other characteristics. To incorporate NWI wetland data into our model, we converted the Cowardin wetland codes to a simpler system with fewer wetland classes, based on wetland vegetation and water permanence.

The Cowardin classification system identified 199 wetland types in Iowa. We condensed these into nine wetland types by grouping specific Cowardin codes together (Table 1). Cowardin codes with modifiers indicating a wetland was only intermittently flooded (J), partly drained/ditched (d), or farmed (f) were classified as upland for a tenth type. Iowa wetlands were re-classified in ArcMap by joining the conversion rules to the NWI polygon shapefile and dissolving the shapefile on the new classification to eliminate unnecessary lines.

The dataset used to inform our model combined the 2005–09 survey data and summarized wetland data for each surveyed section (Appendix A). The survey data included the number of indicated pairs observed at each wetland type in the surveyed section summed over the five years and the number of years each section was surveyed. The wetland data included the wetland types, number of wetlands for each type, areas of each wetland type, and total wetland area in the section. The area per wetland type and the total area per section were divided by

Table 1. Rules for converting Cowardin wetland classifications (alpha-numeric codes that describe wetland permanence, substrate and vegetation) to a new, simplified wetland classification based on water permanence and wetland vegetation. Nine wetland types (plus upland) are described in the new wetland classification system.

| New | Lake | Quarry | Semi-permanent Swamp* | Seasonal Swamp* | Temporary Swamp* | Semi-permanent Marsh | Seasonal Marsh | Temporary Marsh | River | Upland* |
|---|---|---|---|---|---|---|---|---|---|---|
| Cowardin Class | L1UB | PUBGx | PFOF, PFOG, PFOK | PFOBh | PFOA, PFOB | L2EM | PEMC | PEMA | R2 | PSSA |
| | L2UB | PUBHh, PUBHx | PFOHh | PFOCh, PFOCx | PSSAh, PSSAx | PAB | | PEMB | R3 | PSSB |
| | L2AB | PUBKh, PUBKx | PSSFh, PSSFx | PSSC | PSSBh, PSSBx | PEMF, PEMG, PEMK | | | R4 | Modifiers: j, d, f |
| | L2US | | | PUSCh, PUSCx | | PEMBh, PEMBx | | | | |
| | PUSKx | | | | | PUBFh, PUBFx | | | | |
| | | | | | | PUBGh | | | | |

*No geese were observed on these wetland types during 2005–09.

1,000,000 to create more manageable data for the model and easier model convergence.

**Canada goose nesting habitat**

We identified all Iowa sections with potential Canada goose nesting habitat, which was defined as any wetland type on which Canada geese had been observed during any of the five breeding population surveys during 2005–09. If no goose pairs were observed on a particular wetland type, then that wetland type was combined with the upland type. We assumed that sections with no goose nesting habitat would not support any breeding pairs of Canada geese and were excluded from the dataset of sections for which pairs were predicted. This assumption may result in a negligible underestimation of the Canada goose population in Iowa.

Although geese were observed nesting along rivers, not all wetland types classified as river provided adequate nesting habitat. Many river wetland types in Iowa are drainage ditches or narrow headwater streams at which geese are unlikely to nest, and thus were eliminated from the dataset. We did this by excluding the NWI linear shapefile which essentially removed stream orders 1 and 2, and used only the polygons.

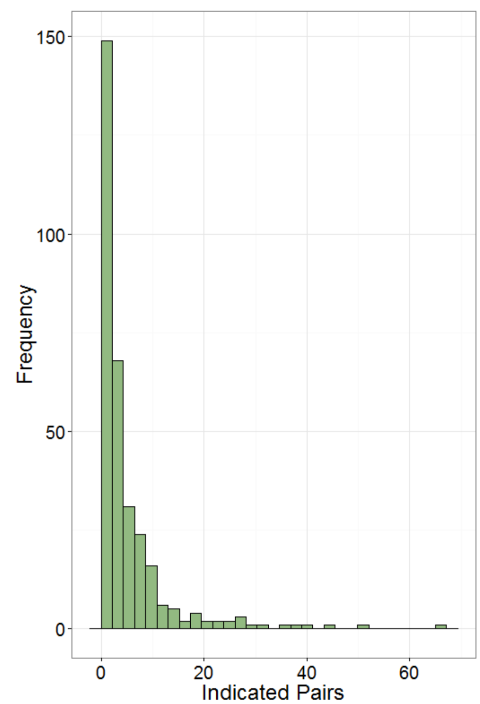



Figure 2. Frequencies of observed Canada goose breeding pairs in 322 square-mile sections in Iowa during five years (2005–2009) of breeding population surveys.

**Model development**

Prior to model development, we conducted an exploratory data analysis which indicated the response variable (survey counts of Canada goose pairs) was Poisson distributed (Figure 2). Because our response variable was count data, a generalized linear model (GLM) with Poisson distribution was the starting point in model development (Zuur et al. 2009). We built and evaluated models using glmer in the ‘lme4’ package (Bates et al. 2014) in R (R Core Team 2013) because it allowed random effects to be incorporated which can be used to account for over dispersion in the data. The most parsimonious model was determined using Akaike’s Information Criterion (AIC; Akaike 1973). We started with the full model which incorporated all *a priori* variables and interactions (Table 2). Because the survey data was a sample of sections used to represent the entire state, we incorporated two random effects for section and individual observation to account for variation contributing to over dispersion in the data. An offset term was included in the model to log transform the number of years each section was surveyed, because some sections were not surveyed all five years due to logistical constraints.

We used backward stepwise procedures to determine which model best predicted the number of Canada goose pairs in each section. To do this, we continually removed the covariate with the lowest absolute value z-value, until removal of a covariate resulted in an increase in the AIC (Arnold 2010). The top model was validated using analysis of residuals.

*Model variable justification*

The number, size, and types of wetlands in a section were potentially informative because Canada geese prefer nest sites that offer visibility as well as protection and sufficient distance from other nesting geese (Cooper 1978). Vegetation characteristics of a wetland impact most of these requirements and wetland types are usually associated with specific vegetation types. For example, swamps are associated with woody vegetation, marshes are associated with herbaceous vegetation, and lakes are associated with little vegetation except along the shoreline. The area of each wetland type and the total area were incorporated into the model because area can be indicative of water permanence and may limit the density of nests due to territoriality of the

Table 2. Model variables compiled from the National Wetlands Inventory database for Iowa.

| **Variable Name** | **Description** |
|---|---|
| Wetland type | All wetland types found in each section (Lake, Quarry, Seasonal Marsh, Semi-permanent Marsh, Temporary Marsh, River) |
| Wetland number | The number of wetlands per wetland type in each section |
| Wetland area | The sum of wetland areas for each wetland type in each section |
| Total area | The total wetland area (regardless of wetland type) in each section |
| **Interaction Terms** | |
| (Wetland area)$^2$ | |
| Wetland number × Wetland type | |
| Wetland area × Wetland type | |
| **Random Effects** | |
| Individual observation effect | |
| Section effect | |

species (Collias and Jahn 1959; Vermeer 1970; Ewaschuk and Boag 1972; Cooper 1978). The number of wetlands could be a predictor of Canada goose densities because the species relies on multiple wetlands for nesting and brood rearing. Territories are small while nesting and an incubating goose will not go far from the nest (Martin 1964; Ryder 1975), but once the clutch hatches the family unit leaves the nest, sometimes traveling to an entirely different wetland (Cooper 1978) because an area that may provide great nesting habitat may not provide good brood rearing habitat. For example, geese may select a nest site on a muskrat lodge or on an island with tall vegetation (Ewaschuk and Boag 1972; Cooper 1978). A goose protecting goslings, however, needs habitat with good visibility and short grass for feeding (Collias and Jahn 1959; Bruggink et al. 1994). More wetlands could result in less competition for nest sites and more options for raising a brood.

The quadratic of the wetland areas was included in the model because we suspected the relationship between goose densities and wetland size was non-linear. Geese prefer large wetlands with open water (Kaminski and Prince 1977; Hanson 1997); however, larger lakes often have little nesting habitat (Cowardin et al. 1979). Median size wetlands are likely to provide more diverse habitat for nesting and foraging (Kantrud and Stewart 1984). Thus, we hypothesized that median size wetlands were more likely to produce higher densities of nesting geese.

An interaction between the number of wetlands and wetland types was incorporated because we hypothesized that the relationship between goose densities and the number of wetlands would depend on the wetland type. For example, seven semi-permanent marshes should offer more nest sites than seven seasonal marshes. An interaction between wetland area and types was also incorporated because we suspected the relationship between goose densities and wetland size would depend on the wetland type. As an example, a large semi-permanent marsh will likely produce higher densities of breeding pairs than a seasonal wetland of the same size because the characteristics of some wetland types are more conducive to nesting geese.

**Section stratification**

We used the most parsimonious model to predict breeding pair densities for each section in Iowa with potential goose nesting habitat. The model predicted pairs for each wetland type in the section. These predictions were then summed and rounded to the nearest whole number. We then assigned each section to one of four strata based on the number of predicted pairs: (1) 1–2 pairs, (2) 3–6 pairs, (3) 7–12 pairs, and (4) >12 pairs. These intervals were used in order to compare predictions to the 2004 stratification by the Iowa DNR, but they could be altered in the future if the survey design was modified to contain fewer strata. Because pairs were predicted per square-mile section, if a wetland is larger than a square-mile or overlaps multiple sections, then the wetland may not appear correctly stratified at first glance. To interpret goose densities per wetland, multiple sections may need to be summed.

## Results

Canada geese were only observed at six of the nine wetland types during the 2005–09 breeding population surveys. During these surveys, geese were observed at the lake, seasonal marsh, temporary marsh, semi-permanent marsh, quarry, and river wetland types. Geese were not observed at seasonal swamp, temporary swamp, or semi-permanent swamp wetland types, so these were eliminated as potential nesting habitat for Canada geese and combined with the upland type. Other studies (Kossack 1950; Martin 1964; Cooper 1978) have also reported low use of wooded habitat by nesting Canada geese. Of the 56,878 square-mile sections in Iowa, 40,547 (71%) contained potential goose nesting habitat (Figure 3).

The majority of sections with no goose nesting habitat fell within the Des Moines Lobe of the Prairie Pothole Region, which illustrated the effect wetland drainage had on waterfowl habitat in this region (Schrader 1955; Miller et al. 2009). Although the southern part of the state may appear to contain more nesting habitat, this region primarily contains farm ponds and narrow streams which are unattractive to nesting geese.

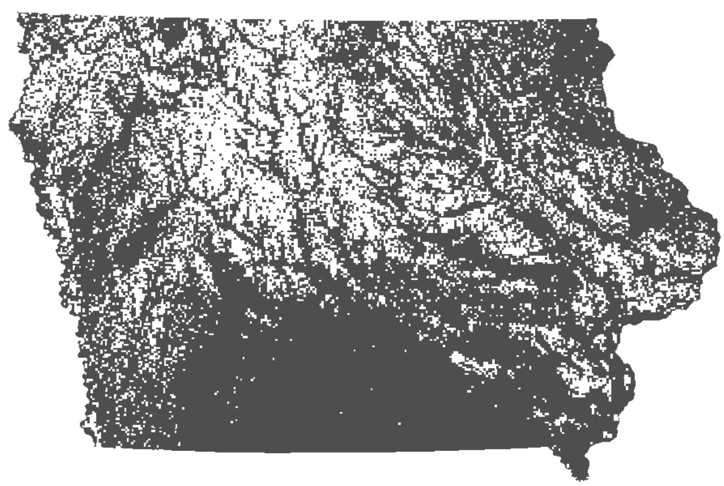


Figure 3. Iowa sections with potential Canada goose nesting habitat based on observations from five years of breeding population survey data.

The global model included five covariates, three interactions, two random effects and an offset term (AIC = 4759). The most parsimonious model included four covariates, two interactions, two random effects, and an offset term (AIC = 4757, Table 3). The top model indicated Canada goose breeding pair densities were a function of wetland type, number of wetlands, area of wetland types, a quadratic of the area of wetland types, an interaction between wetland types and the area of wetland types, and the random effects for observations and sections. Estimates of the explanatory variables are listed in Table 4.

Breeding pair densities were greatest on semi-permanent marshes and quarries (Figure 4). Predicted pairs per section increased with an increase in the number of these wetland types (Figure 5). Lake and quarry wetlands exhibited a weaker correlation between goose densities and numbers of wetlands. There is evidence for a quadratic relationship between goose densities and wetland area for semi-permanent marshes and lakes (Figure 6); however, this relationship appears linear for other wetland types. The model did not perform as well for seasonal marshes and quarries in sections when the number and area of these wetland types were above average, so they were left out of the plot. We found no evidence that Canada goose breeding pair densities were influenced by the total area of water, or that there was an interaction between the number of wetlands and wetland type.

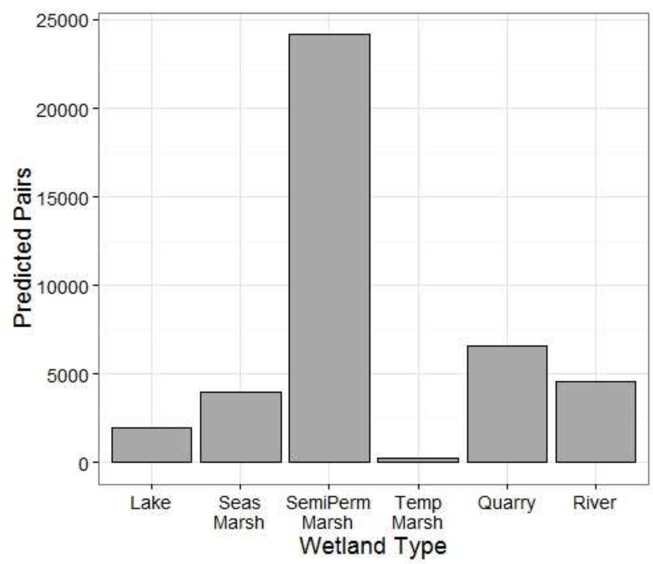



Figure 4. The predicted Canada goose breeding pairs totaled for each wetland type (lake, seasonal marsh, semi-permanent marsh, quarry, and river) across all Iowa sections.

Table 3. Model selection statistics using backward stepwise procedures for Poisson regression models to predict Canada goose breeding pair densities in Iowa. Models were developed to predict Canada goose breeding pairs using wetland information compiled from the National Wetlands Inventory database for Iowa. Variables included in the model were number of wetlands (Number), types of wetlands (Type), the sum of wetland areas for each wetland type (Area), the total area of wetlands (TotalArea), and three interaction terms: 1) a quadratic of the sum of the wetland areas per wetland type (Area^2), 2) the number of wetlands per wetland type and wetland type (Number × Type), 3) and a sum of the areas by wetland type and wetland type (Area × Type). We incorporated two random effects for section (1|STR) and individual observation (1|obs) and an offset term (Yrs).

| **Model** | **Δ AIC*** | $w_i$ | ***K*** | **Deviance** |
|---|---|---|---|---|
| Number + Area + Type + Area × Type + Area^2 + 1\|STR + 1\|obs + offset(Yrs) | 0 | 0.49 | 17 | 4725.6 |
| Number + Area + Type + Number × Type + Area × Type + Area^2 + 1\|STR + 1\|obs + offset(Yrs) | 0.65 | 0.35 | 22 | 4716.3 |
| Number + Area + Type + TotalArea + Number × Type + Area × Type + Area^2 + 1\|STR + 1\|obs + offset(Yrs) | 2.26 | 0.16 | 23 | 4715.9 |
| Number + Area + Type + Area^2 + 1\|STR + 1\|obs + offset(Yrs) | 37.76 | 0.00 | 12 | 4773.4 |

*Best model had an AIC value of 4757.61.

Table 4. Estimates of the best fitted Poisson model to predict Canada goose breeding pair densities in Iowa sections.

| Variable | Value | SE | z | Pr (>\|z\|) |
|---|---|---|---|---|
| **Intercept** | -0.79896 | 0.29570 | -2.702 | 0.00689 |
| **Wetland type:** | | | | |
| **Seasonal Marsh** | -2.87424 | 0.35878 | -8.011 | 1.14e-15 |
| **Semi-permanent Marsh** | -0.32270 | 0.31283 | -1.032 | 0.30229 |
| **Temporary Marsh** | -3.79573 | 0.38451 | -9.872 | <2e-16 |
| **Quarry** | -0.99069 | 0.37159 | -2.666 | 0.00767 |
| **River** | -0.27821 | 0.34163 | -0.814 | 0.41543 |
| **Wetland number** | 0.08772 | 0.01617 | 5.424 | 5.83e-08 |
| **Wetland area** | 3.23288 | 0.72234 | 4.476 | 7.62e-06 |
| **(Wetland area)$^2$** | -1.39881 | 0.27903 | -5.013 | 5.35e-07 |
| **Wetland area×Type:** | | | | |
| **Seasonal Marsh** | 5.03497 | 1.95767 | 2.572 | 0.01011 |
| **Semi-permanent Marsh** | 1.96843 | 0.47692 | 4.127 | 3.67e-05 |
| **Temporary Marsh** | 0.02774 | 2.39123 | 0.012 | 0.99074 |
| **Quarry** | 19.78421 | 4.02957 | 4.910 | 9.12e-07 |
| **River** | -0.69600 | 0.97494 | -0.714 | 0.47530 |

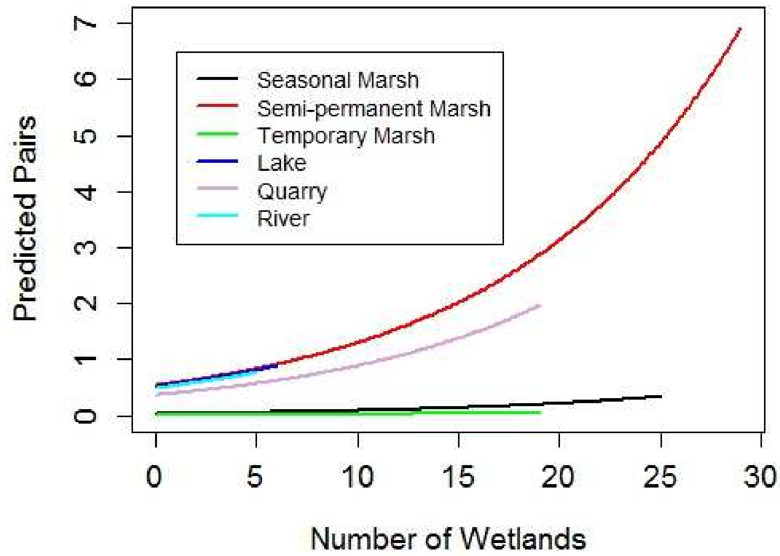



Figure 5. The predicted relationship between the number of Canada goose breeding pairs in a square-mile section and the number of wetlands for each wetland type, based on five years of Canada goose survey data from 322 square-mile sections and wetland information from the National

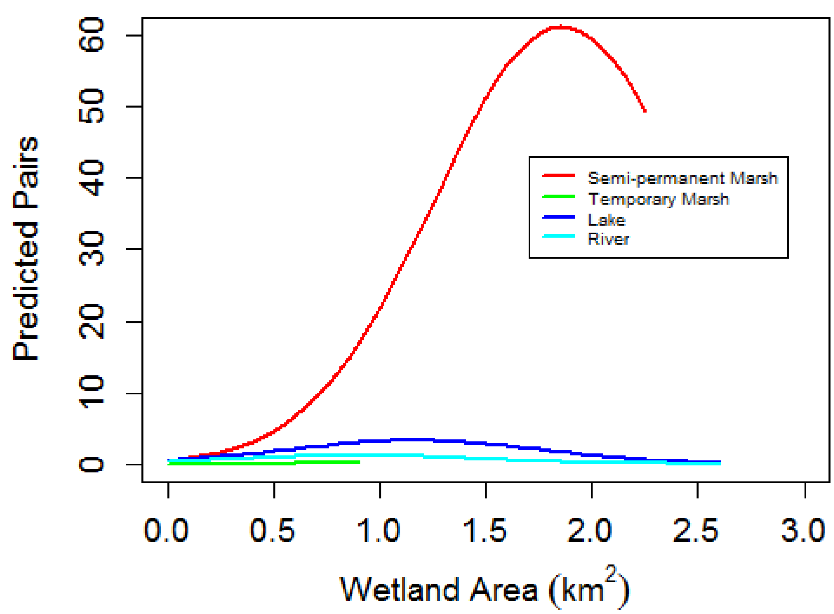



Figure 6. The predicted relationship between the number of Canada goose breeding pairs in a square-mile section and the wetland area (km$^2$) summed for each wetland type, based on five years of Canada goose survey data from 322 square-mile sections and wetland information from the National Wetlands Inventory database for Iowa.

Using NWI data compiled for all sections with nesting habitat, we used the model to predict breeding pair densities for each section in the state (Figure 7). The number of sections assigned to each stratum based on our predictions was similar to Zenner's (2004) stratification (Table 5), It is important to note that the sections from the 2004 stratification have been corrected, which is a necessary step to improve precision of the population estimates. Our sections have yet to be corrected, which requires local biologists to review the predictions. Zenner's (2004) regression analysis largely overestimated breeding pair densities along rivers (Figure 8). Incorporating breeding population survey data and updated NWI data into a model improved the stratification issue along rivers.

Table 5. A comparison of the number of square-mile sections assigned to each stratum of Canada goose breeding pair densities, predicted by Zenner (2004) and Towery et al. (2015).

| Stratum | Sections (Zenner 2004) | Sections (Towery et al. 2015) |
|---|---|---|
| 1-2 pairs | 13,970 | 16,178 |
| 3-6 pairs | 3,061 | 857 |
| 7-12 pairs | 619 | 131 |
| >12 pairs | 110 | 102 |
| **TOTAL** | **17,760** | **17,268** |

## Discussion

Our model improved upon the 2004 stratification by using more statistically rigorous methods to predict Canada goose breeding pairs per section. We incorporated more comprehensive wetland information into our model and utilized survey data to predict pairs. These methods ideally predicted pairs more accurately. If sections are more accurately stratified, then the within-stratum variance will be lower which will improve the variance of the population estimates overall (Lohr 1999). Improvements to the variance of the population estimates will not be evident until each section has been reviewed and corrected by Iowa's field biologists and implemented into the survey. Predictions that have been corrected will further improve the

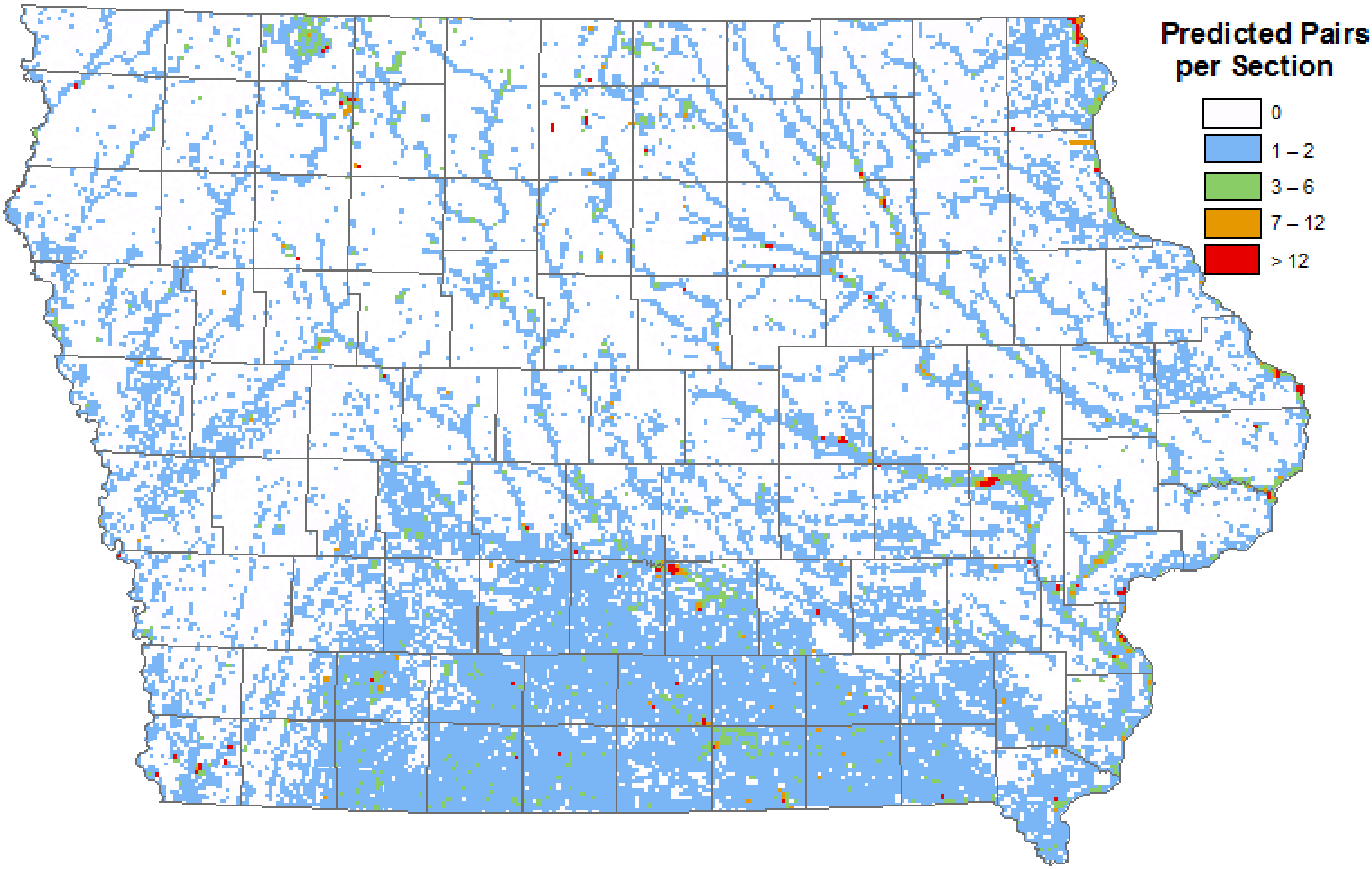
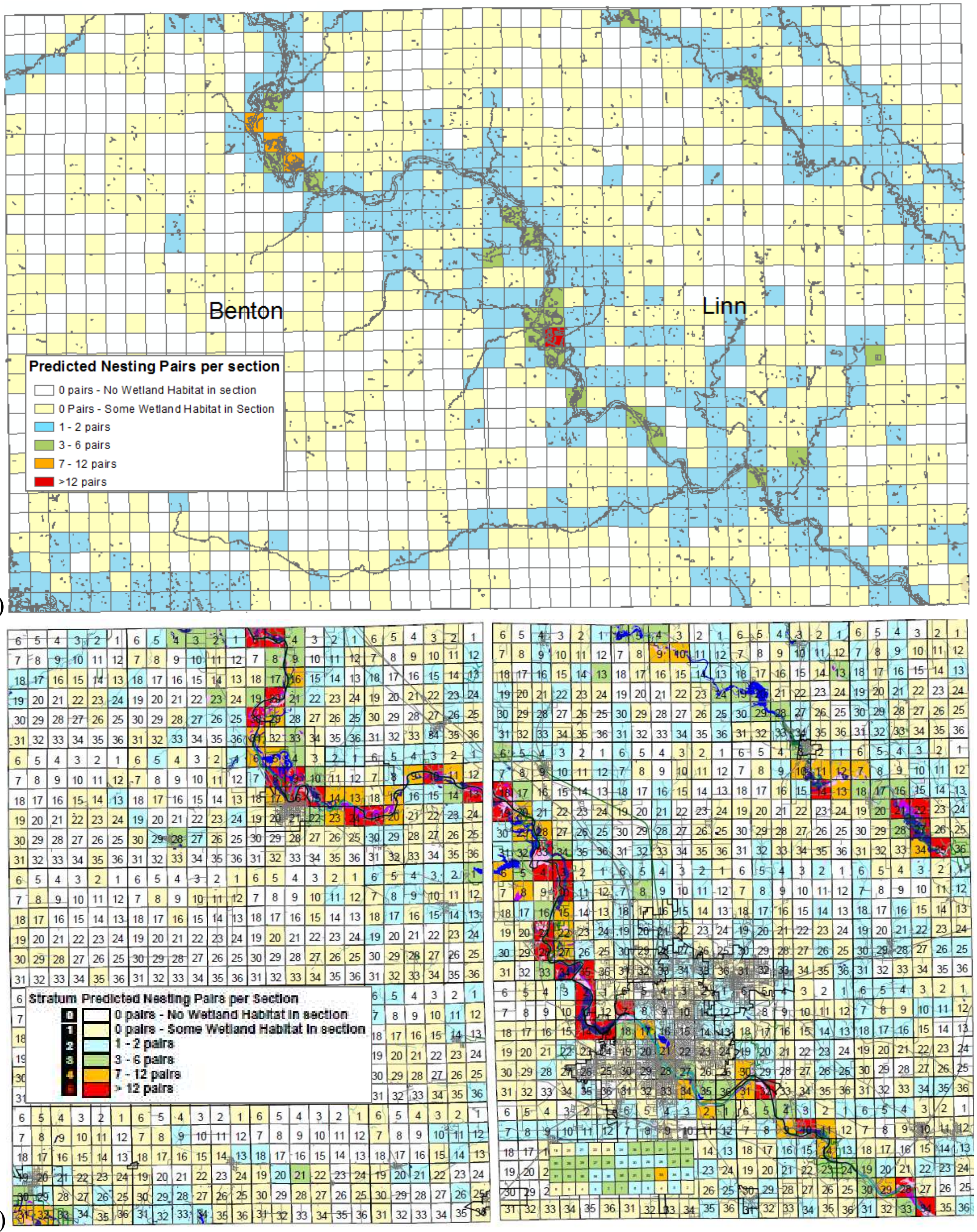



Figure 7. Predicted Canada goose breeding pair densities for each square-mile section in Iowa using five consecutive years of breeding population survey data and National Wetlands Inventory data to inform a generalized linear model. Each section was assigned to a stratum which represents an interval of predicted breeding pairs




a)

b)

Figure 8. Canada goose breeding pair densities in Benton and Linn counties, Iowa predicted by a) Towery et al. (2015) and b) Zenner (2004).

precision of the Canada goose population estimates by ensuring that sections are accurately stratified. With that said, the predictions produced by our model matched our expectations of the Canada goose population in Iowa. For this reason, we did not model average our estimates, even though the second model was competitive.

Few studies have attempted to model the environmental factors that influence breeding pair densities of Canada geese (Kaminski and Prince 1977, Naugle et al. 1997, Fairburn and Dinsmore 2001, Carbaugh et al. 2010). Fairburn and Dinsmore (2001) studied landscape-level influences of wetland bird densities, but found no relationships between a number of measured variables and Canada goose densities. Model variables included total wetland area and area of each wetland type in seventeen wetlands complexes within the PPR (Fairburn and Dinsmore 2001). Our model results also indicated no relationship between goose densities and total wetland area; however, area per wetland type was a significant variable in our model. The contradictory results between the two studies could be related to a difference in sample size and our inclusion of data from additional ecoregions.

Our model results indicated a positive correlation between goose densities and area per wetland type, although this relationship was strongest for semi-permanent marshes and much weaker for lakes, quarries, and rivers. These results support the findings of Naugle et al. (1997) who found that breeding geese selected large semi-permanent wetlands. Semi-permanent marshes and lakes also exhibited a quadratic relationship which suggests that there may be a maximum threshold to the area of these wetland types that will be attractive to nesting geese. Ultimately, however, semi-permanent marshes still predicted high densities at the largest areas and lakes still predicted low densities at the median areas so the relationship probably isn’t very important in predicting goose densities for the breeding population survey stratification.

Kaminski and Prince (1977) studied habitat selection by nesting Canada geese and determined that geese preferred nest sites with at least two hectares of open water and that selection of muskrat lodges or islands for nesting was dependent upon top width of the lodge and percent slope or vegetation density of the island. We found that semi-permanent marshes and quarries produced the highest breeding pair densities, which supports Kaminski and Prince's (1977) findings on the importance of open water around the nest site. Our model indicated that seasonal and temporary marshes produced the lowest densities, which is probably due to the lack of open water or water permanence.

Our model's predictions are conservative and there are some conditions for which the model does not account. For example, we could not incorporate information on urban versus rural wetlands, areas closed to Canada goose hunting, or the presence of islands and/or nest structures. It has been well documented that geese will nest in greater densities on wetlands with islands (Klopman 1958; Vermeer 1970; Ewaschuk and Boag 1972; Giroux 1981), and that urban wetlands often have greater densities of nesting geese than rural wetlands (Conover and Chasko 1985, Ankney 1996, Gosser and Conover 1999). In the absence of this information, predicted numbers of breeding pairs will likely be underestimated in some sections. For this reason, it is critical that the stratification be reviewed and corrected, if necessary, by field biologists before sampling sections to be surveyed.

Future modeling efforts could consider incorporating additional variables such as the perimeter-to-area ratio of the wetlands in each section and the primary land cover surrounding wetlands (e.g., landscape context). In some states, it may be appropriate to incorporate ecoregions because wetland significance might differ depending on its location in the state. We attempted to incorporate ecoregions but the covariate did not perform well for Iowa. We suspect that this could be because wetlands in Iowa are distributed in a way that certain types are typically found in certain ecoregions already (i.e., seasonal marsh in the PPR and farm ponds in southern Iowa). Trying to incorporate ecoregions confounded parameters and over-fitted the model. A hurdle to using these methods is the constant change in the number and quality of wetlands on the landscape, e.g., wetland restoration and wetland drainage. NWI data files may require editing to improve the predictive capabilities of our model.

## Management Implications

This study contributed to the improvement of Iowa's Canada goose breeding population survey by providing a statistically valid stratification process using a GIS, a statistical software program, and updated wetland data. These methods will ideally improve the precision of the population estimates which could improve harvest management strategies. If population estimates are more precise, then there is a higher probability of detecting a change in the population that could be the result of a change in harvest strategies. This allows managers to better determine the impact these decisions are having on the Canada goose population. An improved stratification process could also improve the efficiency of conducting the survey by reducing the necessary sample size and the associated costs. The model and the methods used in its development will be applicable to all Mississippi Flyway states and provinces. We have provided other waterfowl biologists with a method of improving precision of their Canada goose population estimates or designing a more statistically rigorous survey. To implement these methods, other states and provinces would need to record Canada goose locations during a breeding population survey, then obtain the most recent NWI database, convert these wetlands to our developed classification system in ArcMap, join these data with a PLSS layer and summarize by wetland type per section, and use our model to predict breeding pair numbers (Appendix B).

Pairs will be predicted per wetland type, so they should be summed to determine the predicted pairs per section.

## Acknowledgments

We thank Orrin Jones for his input on our redeveloped wetland classification system and model prediction performance. Many thanks to Philip Dixon as well for sharing his statistical expertise. Partial funding for this project was provided through the Iowa Department of Natural Resources Fish and Wildlife Trust Fund Contract CRWB0046-8340-WSUCH and Cooperative Agreement Number G12AC20381 from the United States Geological Survey. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

## References

Akaike H. 1973. Information theory as an extension of the maximum likelihood principle. Pages 267–281 *in* Petrov BN, Csaki F, editors. Second International Symposium on Information Theory. Akademiai Kiado, Budapest, Hungary.

Ankney CD. 1996. An embarrassment of riches: too many geese. Journal of Wildlife Management 60:217–223.

Arnold TW. 2010. Uninformative parameters and model selection using Akaike's Information Criterion. Journal of Wildlife Management 74:1175–1178.

Babcock KM, Humburg DD, Graber DA. 1990. Goose management: the Mississippi Flyway perspective. Transactions of the North American Wildlife Natural Resources Conference 55:313–320.

Bates D, Maechler M, Bolker B, Walker S. 2014. lme4: Linear mixed-effects models using Eigen and S4. R package version 1.1-7, http://CRAN.R-project.org/package=lme4.

Bruggink JG, Tacha TC, Davies JC, Abraham KF. 1994. Nesting and brood-rearing ecology of Mississippi Valley Population Canada geese. Wildlife Monographs No. 126:3–39.

Carbaugh JS, Combs DL, Dunton EM. 2010. Nest-site selection and nesting ecology of giant Canada geese in central Tennessee. Human–Wildlife Interactions 4:207–212.

Collias NE, Jahn LR. 1959. Social behavior and breeding success in Canada geese (Branta canadensis) confined under semi-natural conditions. Auk 76:478–509.

Conover MR, Chasko GG. 1985. Nuisance Canada goose problems in the eastern United States. Wildlife Society Bulletin 13:228–233.

Cooper JA. 1978. The history and breeding biology of the Canada geese of Marshy Point, Manitoba. Wildlife Monographs No. 61:3–87.

Cowardin LM, Carter V, Golet FC, and LaRoe ED. 1979. Classification of wetlands and deepwater habitats of the United States. Publication FWS/OBS-79/31. US Department of Interior, Fish and Wildlife Service, Office of Biological Services, Washington, DC.

Dzubin A. 1969. Assessing breeding populations of ducks by ground counts. Saskatoon Wetlands Seminar. Canadian Wildlife Service Report Series - Number 6:178–237.

Ewaschuk E, Boag DA. 1972. Factors affecting hatching success of densely nesting Canada geese. Journal of Wildlife Management 36:1097–1106.

Fairburn SE, Dinsmore JJ. 2001. Local and landscape-level influences on wetland bird communities of the Prairie Pothole Region of Iowa, USA. Wetlands 21:41–47.

Giroux JF. 1981. Use of artificial islands by nesting waterfowl in southeastern Alberta. Journal of Wildlife Management 45:669–679.

Gosser AL, Conover MR. 1999. Will the availability of insular nesting sites limit reproduction in urban Canada goose populations? Journal of Wildlife Management 63:369–373.

Hanson, HC. 1997. The giant Canada goose. Revised edition. Carbondale, Illinois, USA: Southern Illinois University Press.

Kaminski RM, Prince HH. 1977. Nesting Habitat of Canada geese in Southeastern Michigan. Wilson Bulletin 89:523–531.

Kantrud HA, Stewart RE. 1984. Ecological distribution and crude density of breeding birds of prairie wetlands. Journal of Wildlife Management 48:426–437.

Klopman RB. 1958. The nesting of the Canada goose at Dog Lake, Manitoba. Wilson Bulletin 70:168–183.

Kossack CW. 1950. Breeding habits of Canada geese under refuge conditions. American Midland Naturalist 43:627–649.

Leafloor JO, Abraham KF, Caswell FD, Gamble KE, Helm RN, Humburg DD, Lawrence JS, Luukkonen DR, Pritchert RD, Warr EL, Zenner GG. 2004. Canada goose management in the Mississippi Flyway. *Pages* 22–36 *in* Moser TJ, Lien RD, Vercauteren KC, Abraham

KF, Andersen DE, Bruggink JG, Coluccy JM, Graber DA, Leafloor JO, Luukkonen DR, Trost RE, editors. Proceedings of the 2003 International Canada Goose Symposium, 19–21 March 2003, Madison, Wisconsin, USA.

Lohr, SL. 1999. Sampling: design and analysis. Pacific Grove, California, USA: Duxbury Press.

Malecki RA, Caswell FD, Bishop RA, Babcock KM, Gillespie MM. 1981. A breeding-ground survey of EPP Canada geese in northern Manitoba. Journal of Wildlife Management 45:46–53.

Martin FW. 1964. Behavior and survival of Canada geese in Utah. Utah Dept. Fish Game Bull. 64:1–89.

Miller BA, Crumpton WG, van der Valk AG. 2009. Spatial distribution of historical wetland classes on the Des Moines Lobe, Iowa. Wetlands 29:1146–1152.

Naugle DE, Gleason JS, Jenks JA, Higgins KE, Mammenga PW. 1997. Factors influencing wetland use by Canada geese. Wetlands 17:552–558.

R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Ryder JP. 1975. The significance of territory size in in colonial nesting geese—an hypothesis. Wildfowl 26:114–116.

Schneider JP, Tacha CT, Leafloor JO. 1994. Potential predictors of numbers of Canada goose nests from aerial surveys. Wildlife Society Bulletin 22:431–436.

Schrader TA. 1955. Waterfowl and the potholes of the north central states, in The yearbook of agriculture 1955: Washington, D.C., U.S. Department of Agriculture, 84th Congress, 1st Session, House Document no. 32:596–604.

Trost RE, Gamble KE, Nieman DJ. 1990. Goose surveys in North America: current procedures and suggested improvements. Transactions of the North American Wildlife Natural Resources Conference 55:338–349.

Vermeer K. 1970. A study of Canada geese, *Branta canadensis*, nesting on islands in southeastern Alberta. Canadian Journal of Zoology 48:235–240.

Zuur AF, Ieno EN, Walker NJ, Saveliev AA, Smith G. 2009. Mixed Effects Models and Extensions in Ecology with R. *Springer, New York.*

# CHAPTER 3: LONG-TERM CHANGES IN CANADA GOOSE NEST SUCCESS AND NEST DENSITIES AT AN IOWA WETLAND COMPLEX

A paper to be submitted to *Prairie Naturalist*

BRENNA N. TOWERY[1], ROBERT W. KLAVER[2], AND GUY G. ZENNER[3]

[1]Department of Natural Resource Ecology and Management, Iowa State University, Ames, IA 50011;

[2]U.S. Geological Survey, Iowa Cooperative Fish and Wildlife Research Unit, Iowa State University, Ames, IA 50011,

[3]Iowa Department of Natural Resources, Clear Lake, IA 50428

**Abstract**

Our study investigated giant Canada goose (*Branta canadensis maxima*) nest densities and nest success on extant islands at Rice Lake Wildlife Management Area (WMA) and compared these observations to estimates from a study conducted during 1988–91. We monitored 49 nests on Rice Lake and 48 nests on the adjacent slough (Joice Slough) in 2013 and 32 nests on Rice Lake and 55 nests on the Joice Slough in 2014. In 2013, nest densities averaged 48 nests/ha on Rice Lake and 51 nests/ha on the Joice Slough. In 2014, nest densities averaged 25 nests/ha on Rice Lake and 62 nests/ha on the Joice Slough. Nest success was calculated using apparent estimation methods. In 2013, nest success was 27% on Rice Lake and 13% on the Joice Slough. In 2014, nest success was 38% on Rice Lake and 55% on the Joice Slough. Nest densities and nest success at Rice Lake WMA were lower than they were 25 years ago (1988–91). Nest site availability was reduced, however, because the lake's water level was lowered by the Iowa Dept. of Natural Resources (DNR) for the purpose of renovating the fish population, enhancing aquatic vegetative communities, and improving water quality. This may have reduced

nest success in 2013. Nest success rebounded in 2014 perhaps because Canada geese adapted their nesting behavior to lowered water levels in 2014 or because the stable water level provided better nesting conditions. This study will allow the Iowa DNR to compare Canada goose nest success and island use at Rice Lake WMA in future years following the shallow lake restoration project.

**Keywords** *Branta canadensis maxima*, giant Canada goose, Iowa, islands, nest densities, nest success.

## Introduction

Giant Canada geese (*Branta canadensis maxima*) were extirpated from Iowa by the early 1900s due to unregulated hunting, egg gathering, and wetland drainage in the 19$^{th}$ century (Bishop 1978). Efforts to reintroduce the species in Iowa began in 1964 (Bishop and Howing 1972). The reintroduction program involved holding flocks of flightless breeding adult geese at 15 wetland areas across Iowa for the purpose of repopulating the surrounding wetland habitat with their free-flying offspring, as well as releasing flightless goslings at 28 different wetland sites across Iowa during 1983–90 (Zenner and LaGrange 1998a). One of the original restoration flocks was at Rice Lake Wildlife Management Area (WMA) in north-central Iowa, an area that lies in the southernmost portion of the Prairie Pothole Region (PPR).

Giant Canada goose (hereafter Canada goose) nest success and nest densities were investigated at Rice Lake during 1988–91 (Zenner and LaGrange 1998b). At that time, islands, nest structures, and muskrat houses provided potential nest sites on Rice Lake WMA; islands, however, were the primary nesting habitat used by geese. Over the course of the 1988–91 study, habitat conditions deteriorated because a drought lowered water levels and exposed islands to increased predator activity. Despite the drought conditions, Canada goose nest densities (68–158 nests/ha) and nest success (40–58%) were high on the islands at Rice Lake (Zenner and LaGrange 1998b).

In 2013 and 2014, we re-visited Rice Lake WMA to investigate Canada goose nesting activity on extant islands at Rice Lake and the adjacent Joice Slough. In the 25 years since the original study, habitat conditions had changed: nest structures and muskrat houses were no longer available as nesting sites and many islands had become densely vegetated with brush and trees. Considering Iowa's Canada goose breeding population increased 10-fold in the past 25 years (Iowa DNR 2014) and upland and wetland habitats had changed substantially on the lake, we were interested in comparing Canada goose nest success and nest densities on extant islands to those observed by Zenner and LaGrange (1998b) on Rice Lake during 1988–91.

## Study Area

Rice Lake WMA was a 741-ha area located in north-central Iowa along the eastern edge of the Des Moines Lobe of the PPR (Figure 1). The WMA contained Rice Lake, a 409-ha shallow, natural lake with an average depth of 1 m, a maximum depth of 3 m and 20 natural islands ranging in size from 0.04 to 3.9 ha, and the Joice Slough, a 73-ha marsh with a maximum depth of 1 m and 15 natural islands ranging in size from 0.02 to 3.19 ha (Zenner and LaGrange 1998b).

In 2006, the Iowa DNR implemented a Shallow Lakes Initiative to improve water quality, fisheries and wildlife habitat and populations, and recreational opportunities (Evelsizer and Fisher 2006). Drought conditions in 2012 provided an opportunity to renovate Rice Lake, the water quality of which had become highly degraded due to the lack of aquatic vegetation, the presence of invasive fish species, and inadequate water level management capabilities (Iowa DNR 2013). In April 2013, near the start of the Canada goose nesting season, the DNR lowered

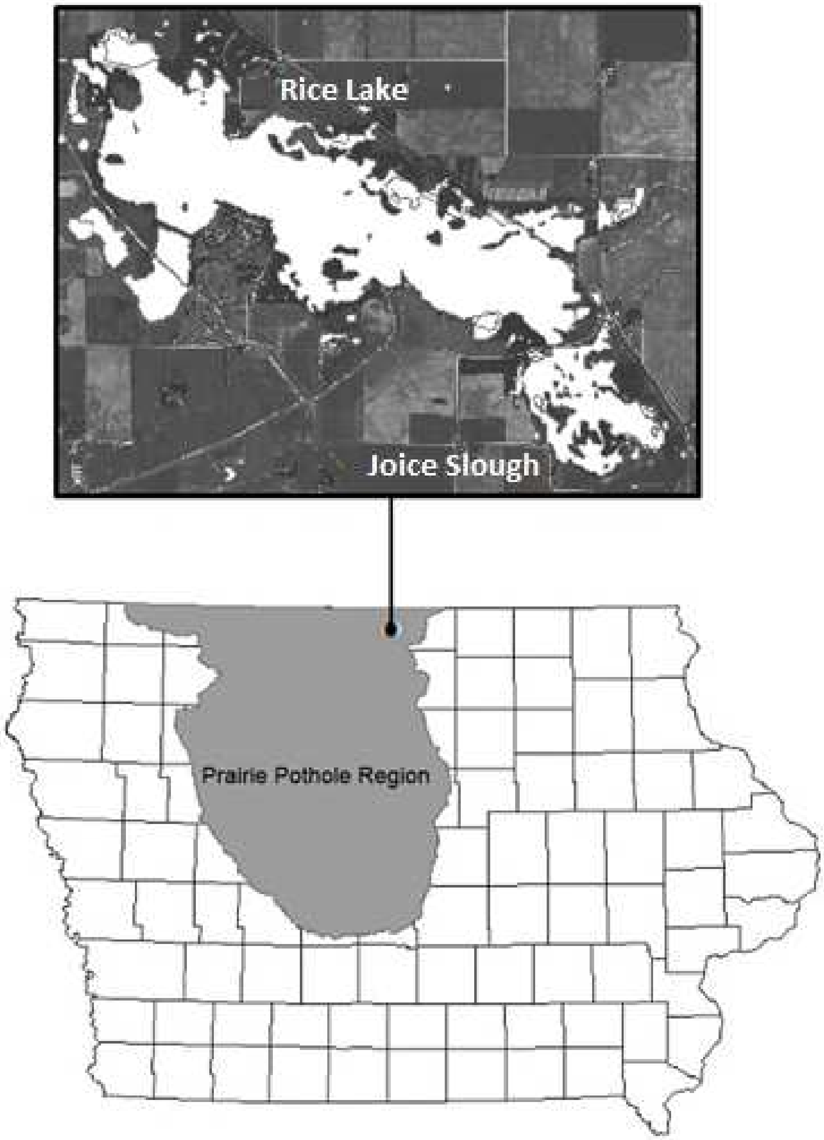



Figure 1. Map of Iowa indicating the Des Moines Lobe of the Prairie Pothole Region. Inset shows the Rice Lake WMA study site.

Rice Lake's water level by 1 m to expose mudflats and re-vegetate shallow water zones, a process commonly referred to as a drawdown. As a result of this management action and drought conditions in 2013 and 2014, the lake's water levels were comparable to conditions during the study conducted by Zenner and LaGrange (1998b) in 1988–91. The water level at the Joice Slough was not manipulated, but experienced natural fluctuations.

# Methods

## Nest Searches

We monitored Canada goose nests on islands at Rice Lake and the Joice Slough from 6 April–17 June 2013 and from 18 April–17 June 2014. In 2013 and 2014, only 10 of the 35 islands on the WMA were extant islands, i.e., completely surrounded by water, four of which were on Rice Lake and six were on the Joice Slough. All accessible islands, extant or not, were searched systematically for active, abandoned and depredated nests.

Each located nest was assigned a unique number and its GPS coordinates recorded. A wooden tongue depressor marked with the ID number was placed north of the nest to differentiate among nests on each island. Some evidence suggests that nest markers can alert predators to a nest's location (Hammond and Forward 1956). By using natural colored tongue depressors, we felt that the nest marker would not serve as a visual cue to predators. We recorded the number of eggs in the nest and their incubation age (in days) to predict hatch date. The age of the clutch was determined using a field candling device (Weller 1956, Walter and Rusch 1997, Reiter and Anderson 2008). Egg handling procedures and other study methods were approved by the Iowa State University Institutional Animal Care and Use Committee (protocol #11–12–7460–Q).

We checked nests three times during the nesting period and once post-hatch to determine nest fate. A nest was considered successful if at least one egg hatched (Mayfield 1961). A successful nest was identified by the presence of eggshell fragments and detached intact membranes in the nest (Girard 1939, Cooper 1978). Nests with remains of eaten eggs were classified as depredated. Nest predators were detected using camera traps placed near a sample of nests. Cameras were placed 1–2 m from the nest.

**Statistical Analysis**

To make an analogous comparison to the nest success results reported by Zenner and LaGrange (1998b), we calculated apparent nest success using only nests located on extant islands. Canada geese nested on islands connected to the mainland during both this and the study conducted by Zenner and LaGrange (1998b); we excluded these nests from the apparent nest success analysis. Apparent nest success is simply the proportion of total nests that hatched at least one egg (Johnson 1979). This method, in most cases, is considered unreliable for estimating nest success because it can bias estimates high due to the fact that unsuccessful nests are usually not found and nests found later in incubation are more likely to be successful (Mayfield 1961). Island-nesting geese, however, may be an exception to this bias because the search area is confined and most failed nests are located (Johnson and Shaffer 1990). All nests found active, depredated or abandoned were recorded and incorporated into the total number of initiated nests for both this study and the 1988–91 study (Zenner and LaGrange 1998b). We are confident that active, depredated, and abandoned nests found during this study and Zenner and LaGrange's 1988–91 study had equal detection probabilities because goose eggs are conspicuous and vegetation development was low during nest searches. There are more statistically rigorous methods of estimating nest success, e.g., the nest survival model (Dinsmore et al. 2002) in Program MARK (White and Burnham 1999), but we did not expect those methods to produce substantially different estimates from apparent nest success in this case. We used Welch's *t*-test to test for differences in nest densities and nest success within Zenner and LaGrange's (1998b) study and this study, and between the two studies. The Pearson correlation coefficient was calculated to evaluate the relationship between water level and depredation rate.

## Results

### Water Levels and Nest Densities

During 1988–91, water levels at Rice Lake ranged from 0.43 to 1.22 m below crest (Figure 2). During this study, water levels at Rice Lake ranged from 0.52 to 1.17 m below crest. After the drawdown in April 2013, the water level at Rice Lake averaged 0.84 m below crest. In 2014, the water level continued to fall, averaging 0.9 m below crest. During our study, water levels at the Joice Slough increased from 0.04 m below crest in 2013 to crest in 2014. Although the Joice Slough water level was not manipulated by the Iowa DNR, it fluctuated due to its smaller size. Prior to 2013, the slough was dry as a result of natural drought (T. J. Herrick, Iowa DNR, unpublished data).

Although water levels varied throughout both studies, interior island sizes did not drastically change. Island status, however, was highly affected by dropping water levels. Many islands near the shoreline were no longer surrounded by water and became connected to the mainland (Table 1). During 1988–91, the Joice Slough was completely dry and only four extant islands were available to geese nesting on Rice Lake (Zenner and LaGrange 1998b). Two of the four islands monitored during 1988–91 were only exposed once the lake dropped lower than 0.90 m below crest. During our study, water levels remained at or above this threshold. Four extant islands were available to geese nesting on Rice Lake during 2013–14, but only two of them were the same islands monitored by Zenner and LaGrange (1998b).

Although water levels were comparable in 1988 and 2013 (pre-drawdown) and in 1989 and 2014 (Figure 2), average nest densities were lower during this study ($t_{14} = -4.42$, $p < 0.001$; Table 2). In response to reduced water levels, average nest densities on islands increased from 1988 to 1990 (68 to 153 nests/ha) ($t_4 = -5.73$, $p = 0.005$). From 2013 to 2014 average nest

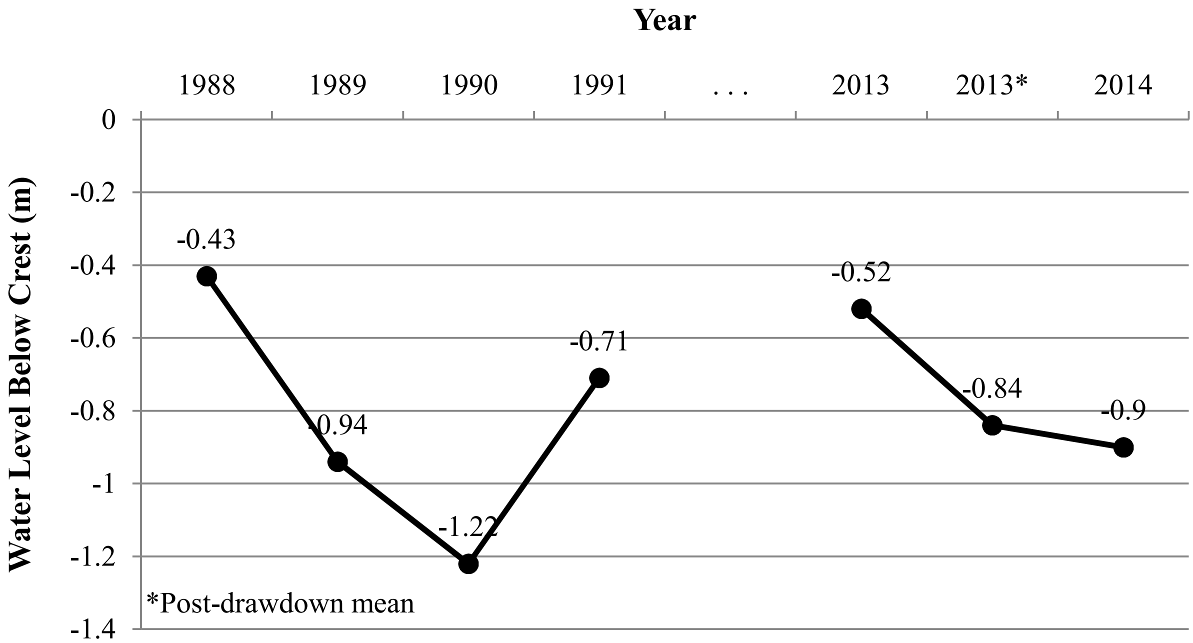



Figure 2. Rice Lake water levels (m) relative to crest during natural drought (1988–91) (originally published by Zenner and LaGrange (1998b)) and during an Iowa Dept. of Natural Resource-initiated drawdown (2013–14). Water levels pre-drawdown and post-drawdown are shown for 2013. Post-drawdown water level was averaged from weekly measurements taken by the DNR in April and May.

Table 1. Number of extant (surrounded by water) and former (connected to the mainland) islands available to and used by nesting giant Canada geese (*Branta candensis maxima*) at Rice Lake Wildlife Management Area (WMA), Iowa, 2013–14.

| | | **Extant Islands** | | **Former Islands** | |
|---|---|---|---|---|---|
| | | **Available** | **Used** | **Available** | **Used** |
| **Rice Lake** | **2013** | 4 | 4 | 16 | 6 |
| | **2014** | 4 | 3 | 16 | 0 |
| **Joice Slough** | **2013** | 6 | 6 | 9 | 2 |
| | **2014** | 7 | 6 | 8 | 0 |

Table 2. Giant Canada goose nest densities on extant islands at Rice Lake Wildlife Management Area (WMA), Iowa during 1988–91 and 2013–14.

| **Year** | **Density per island (Nests/ha)** | | | | | | **Mean Density** |
|---|---|---|---|---|---|---|---|
| | **RL‡ 1** | **RL 2** | **RL 3*** | **RL 4*** | **RL 5*** | **RL 6*** | |
| **1988†** | 62 | 74 | – | – | – | – | 68 |
| **1989†** | 121 | 49 | – | – | – | – | 85 |
| **1990†** | 169 | 173 | 114 | 154 | – | – | 153 |
| **1991†** | 250 | 173 | 68 | 141 | – | – | 158 |
| **2013** | 58 | 38 | – | – | 54 | 40 | 48 |
| **2014** | 78 | 19 | – | – | 0 | 2 | 25 |
| | **JS‡ a** | **JS b** | **JS c** | **JS d** | **JS e** | **JS f** | |
| **2013** | 100 | 58 | 13 | 46 | 41 | 29 | 48 |
| **2014** | 76 | 50 | 23 | 115 | 35 | 71 | 62 |

‡RL = Rice Lake islands, JS = Joice Slough islands
*Islands RL 3 and RL 4 were not exposed during 1988–89 and 2013–14. Islands RL 5 and RL 6 were connected to the mainland during 1988–91.
†Data published by Zenner and LaGrange (1998b).

densities on Rice Lake islands declined (48 to 25 nests/ha), but the difference was not significant ($t_3$ = 1.20, $p$ = 0.153). This is because changes in nest densities on individual islands at Rice Lake between 2013 and 2014 were highly variable (Table 2). The average nest densities on Joice

Slough islands during this time increased (48 to 62 nests/ha), but also was not significant ($t_{10}$ = -0.76, $p$ = 0.232) due to the variable densities of nests.

**Nest Success**

During 1989–91 Canada geese initiated nests on four extant islands on Rice Lake and nest success ranged from 40–58% (Zenner and LaGrange 1998b; Table 3). During our 2-year study, Canada geese nested on four Rice Lake islands and six Joice Slough islands. Nest success on Rice Lake islands increased from 27% to 38%, and nest success on Joice Slough islands increased from 13% to 55%. Mean nest success during 2013–14 (34%) was lower than during 1989–91 (50%), but not significantly ($t_5$ = -1.67, $p$ = 0.079).

During the 1989–91 Rice Lake study, abandonment rates were much higher than depredation rates (Table 3). Depredation rates, although modest at ≤ 12%, were highest when Rice Lake water levels were lowest (Zenner and LaGrange 1998b, Figure 2). We observed very high depredation rates (Table 3), which increased from 41% to 53% when water levels lowered from 2013 to 2014 on Rice Lake, and decreased from 47% to 38% when water levels increased from 2013 to 2014 at the Joice slough. However, there was not a strong correlation between water levels and depredation rates ($r_5$ = 0.58, $p$ = 0.169). This result could be due to our excluding former islands. Also, there is the possibility that some nests were abandoned prior to being destroyed by predators. Camera traps indicated nests were destroyed by coyotes (*Canis latrans*), raccoons (*Procyon lotor*), American crows (*Corvus brachyrhynchos*), and, in two instances, by local farm dogs (*Canis lupus familiaris*).

Apparent nest success on former islands was extremely low. In 2013, 71 nests were initiated on former Rice Lake islands and 1% were successful. Ninety percent of nests on former Rice Lake islands were depredated, and 9% were abandoned. Nine nests were initiated on former

Table 3. Giant Canada goose production and nest fates at Rice Lake WMA, Iowa during 1989–91 and 2013–14.

| | Year | Hatched Nests | Initiated Nests | % Hatched | % Depredated | % Abandoned |
|---|---|---|---|---|---|---|
| Rice Lake | 1989$^{\Delta}$ | 28 | 52 | 54% | 12% | 34% |
| | 1990$^{\Delta}$ | 81 | 140 | 58% | 11% | 31% |
| | 1991$^{\Delta}$ | 61 | 150 | 40% | 0% | 60% |
| | 2013$^{\dagger}$ | 13 | 49 | 27% | 40% | 33% |
| | 2014$^{\dagger}$ | 12 | 32 | 38% | 53% | 9% |
| Joice Slough | 2013$^{\ddagger}$ | 6 | 46 | 13% | 78% | 9% |
| | 2014$^{\ddagger}$ | 30 | 55 | 55% | 38% | 7% |

$^{\Delta}$Data from four Rice Lake islands: RL1, RL2, RL3 and RL4; originally published by Zenner and LaGrange (1998b).
$^{\dagger}$Data from four Rice Lake islands: RL1, RL2, RL5, and RL 6.
$^{\ddagger}$Data from six Joice Slough islands: JS a, JS b, JS c, JS d, JS e, JS f

Joice Slough islands in 2013 and 11% were successful. Eighty-nine percent of nests on former Joice Slough islands were depredated. In 2014, former islands on Rice Lake were inaccessible due to the drawdown, and no geese nested on former islands on Joice Slough.

## Discussion

### Water Levels and Nest Densities

Over the past 25 years, Canada goose nest densities on islands have declined at Rice Lake WMA, but seemingly so has the Canada goose population at this site. The reason for this is unclear. One potential cause may be changes to the available nesting sites. In the late 1980s, geese could use nest structures and muskrat houses as alternative nesting sites, both of which were not available during this study. The only nest sites available in recent years at Rice Lake that offered protection from predators were islands, and ecological succession had changed the vegetation on these islands so that they were dominated by dense brush and trees. Intuitively, goose densities should have increased on islands when alternative nest sites were no longer available, but nesting geese are highly territorial and densities may have been at their peak during 1988–91. The availability of nest sites is limited by the island size. Also, nesting geese prefer to use areas with a clear field of vision (Hanson 1997) and typically select islands free of dense vegetation (Kaminski and Prince 1977). It may be that the degraded nest site conditions made Rice Lake islands less attractive to nesting geese.

Another major difference in study site conditions between the original study and our study was the shallow lake renovation activity. Water levels dropped gradually due to natural drought during 1988–91 at Rice Lake whereas in 2013 they were lowered much more quickly (0.6 m in one month). This rapid change in water level did not give geese a chance to adapt and alter their nest site locations in 2013. Thus many geese inadvertently nested on islands that became attached to the mainland.

Multiple studies of island-nesting Canada geese have found that, when water levels declined, geese nested in higher densities on remaining islands (Ewaschuk and Boag 1972, Zenner and LaGrange 1998b). We found that nest densities on extant islands at Rice Lake drastically declined between 2013 and 2014, with the exception of RL1, which is the island with the best nesting conditions (i.e., no land predators, further from mainland, large in size, not brushy but with low shrubs for cover). Nest densities on Joice Slough islands increased slightly from 2013 to 2014 indicating that some nesting pairs may have abandoned their Rice Lake nest sites for Joice Slough islands. Canada geese exhibit nest site fidelity to some extent (Cooper 1978, Hanson 1997), but it's possible that the degraded nesting conditions and subsequent failed nests in 2013 resulted in some geese nesting elsewhere or not at all in 2014.

**Nest Success**

On average, nest success rates in 2013–14 were slightly lower than rates reported by Zenner and LaGrange (1998b). Nest success was particularly low in 2013, the first year the water level was lowered. Although drought severely affected nesting conditions at Rice Lake in 1990 and 1991, water levels were stable throughout the nesting season (from nest establishment to hatch). In 2013, most geese selected nest sites at Rice Lake based on pre-drawdown water levels. When the water level suddenly dropped, many islands were no longer safe from terrestrial predators, resulting in a large proportion (41%) of failed nests due to depredation. Although Rice Lake water levels were slightly lower in 2014 than in 2013, Joice Slough water levels increased. Nest success likely rebounded in 2014 because water levels were more stable which provided better nesting conditions. Ideally, it would have been useful to monitor nest success and densities on islands once Rice Lake was restored to its normal level. However, that was not an option as the water level was not restored in 2014 due to a continuation of the drawdown. We suspect that once the water level is restored to crest and more islands are available for nesting, nest densities and success will increase or stabilize.

The lake renovation project at Rice Lake will undoubtedly improve water quality, aquatic vegetation abundance and diversity, fisheries and wildlife habitat, and recreational opportunities. There are multiple advantages to shallow lake renovations. This study, however, demonstrated that the renovation process can have substantial negative impacts on some wildlife species.

Additionally, this study provided support that the apparent estimator is a reliable method of estimating nest success for island nesting geese (Johnson and Shaffer 1990, Towery 2015). Our estimates of nest success at Rice Lake during 2013–14 using apparent estimation methods (2013 = 0.27, 2014 = 0.38) were similar to the estimates produced by the nest survival model in Program MARK (White and Burnham 1999; 2013 = 0.11, 2014 = 0.35; Towery 2015). Detectability was high enough during this study for an accurate measure of nest success. Nests found depredated or abandoned during searches were incorporated into the total number of initiated nests for the apparent estimator because excluding them biases the estimate high due to the fact that nests found later in incubation are more likely to hatch (Mayfield 1961).

## Management Implications

Shallow lake renovations are currently a major focus for the Iowa DNR, with most proving highly successful at achieving desired objectives. Despite the positive results obtained from lake renovation projects, this study demonstrated that large-scale changes to wetland habitats can have substantial negative impacts. The low nest success rate we observed for Canada geese nesting at Rice Lake in 2013 were most likely due to the timing of the drawdown. These impacts could potentially have implications for other wetland species. We suspect this negative impact could be avoided by lowering the water level after the waterfowl nesting season is complete or during late fall/winter so the water level is low before geese arrive in the spring.

In addition, the Rice Lake WMA very likely would accommodate more nesting geese if vegetation on the islands was managed to favor them. Dense tree and shrub cover on most of the islands appears to discourage goose use.  Shrub and tree cover could be removed from some islands, and nesting goose use of these managed islands could be compared to use of unmanaged islands. If nesting goose use increases on managed islands, tree and shrub densities on islands should be restored to levels observed on islands when the lake was restored in the mid-1940s.

## Acknowledgments

We thank P. Bartelt, J. Godwin, S. Handrigan, O. Jones, and G. Zenner for their efforts in nest monitoring, the Iowa DNR for providing field housing, and J. Morris for access to his Jon boat. Partial funding for this project was provided through the Iowa Department of Natural Resources Fish and Wildlife Trust Fund Contract CRWB0046–8340–WSUCH and Cooperative Agreement Number G12AC20381 from the United States Geological Survey. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

## Literature Cited

Bishop, R. A., and R. G. Howing. 1972. Re-establishment of the giant Canada goose in Iowa. Proceedings of the Iowa Academy of Science 79:14–16.

Bishop, R. A. 1978. Giant Canada geese in Iowa. Iowa Conservationist 37:5–12.

Dinsmore, S. J., G. C. White, and F. L. Knopf. 2002. Advanced techniques for modeling avian nest survival. Ecology 83:3476–3488.

Evelsizer, V., and M. Fisher. 2006. Protocol for monitoring the ecological condition of shallow lakes before and after renovation. Iowa DNR, Watershed Monitoring and Assessment Section: Iowa City, IA.

Ewaschuk, E., and D. A. Boag. 1972. Factors affecting hatching success of densely nesting Canada geese. Journal of Wildlife Management 36:1097–1106.

Girard, G. L. 1939. Life history of the shoveler. Transactions of the North American Wildlife Conference 4:364-371.

Giroux, J. F. 1981. Use of artificial islands by nesting waterfowl in southeastern Alberta. Journal of Wildlife Management 45:669–679.

Hammond, M. C., and W. R. Forward. 1956. Experiments on causes of duck nest predation. Journal of Wildlife Management 20:243–247.

Hanson, H. C. 1997. The Giant Canada Goose. Revised edition. Illinois Natural History Survey: Carbondale, Illlinois, USA.

[Iowa DNR] Iowa Department of Natural Resources. 2002. Iowa Canada goose management plan. DNR State Wildlife Management Plan: Clear Lake, Iowa, USA.

[Iowa DNR] Iowa Department of Natural Resources. 2013. Rice Lake management plan. DNR Management Plan: Ventura, Iowa, USA.

[Iowa DNR] Iowa Department of Natural Resources. 2014. Trends in Iowa wildlife populations and harvest - 2013. DNR Logbook: Boone, IA.

Johnson, D. H., and T. L. Shaffer. 1990. Estimating nest success: when Mayfield wins. Auk 107:595–600.

Kaminski, R. M., and H. H. Prince. 1977. Nesting Habitat of Canada Geese in Southeastern Michigan. Wilson Bulletin 89:523–531.

Klopman, R. B. 1958. The nesting of the Canada goose at Dog Lake, Manitoba. Wilson Bulletin 70:168–183.

Mayfield, H. F. 1961. Nesting success calculated from exposure. Wilson Bulletin 73:255–261.

Reiter, M. E., and D. E. Andersen. 2008. Comparison of the egg flotation and egg candling techniques for estimating incubation day of Canada goose nests. Journal of Field Ornithology 79:429–437.

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295–297.

Toledo, D,, L. B. Abbott, and J. E. Herrick. 2008. Cover pole design for easy transport, assembly, and field use. Journal of Wildlife Management 72:564–567.

Towery, B. N. 2015. The distribution and nest survival of Giant Canada Geese breeding in Iowa. Master's Thesis, Iowa State University, Ames, Iowa, USA.

Walter, S. E., and D. H. Rusch. 1997. Accuracy of egg flotation in determining age of Canada Goose nests. Wildlife Society Bulletin 25:854–857.

Weller, M. W. 1956. A simple field candler for waterfowl eggs. Journal of Wildlife Management 20:111–113.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46 Supplement:120–138.

Zenner, G. G. and T. G. LaGrange. 1998a. Giant Canada geese in Iowa: restoration, management, and distribution. Pages 303–309 *in* D. H. Rusch, M. D. Samuel, D. D. Humburg, and B. D. Sullivan, eds. Biology and management of Canada geese. Proceedings of the International Canada Goose Symposium, Milwaukee, Wisconsin, USA.

Zenner, G. G. and T. G. LaGrange. 1998b. Densities and fates of Canada goose nests on islands in north-central Iowa. Pages 53–59 *in* D. H. Rusch, M. D. Samuel, D. D. Humburg, and B. D. Sullivan, eds. Biology and management of Canada geese. Proceedings of the International Canada Goose Symposium, Milwaukee, Wisconsin, USA.

# CHAPTER 4. CANADA GOOSE NEST SURVIVAL AT RURAL WETLANDS IN NORTH-CENTRAL IOWA

A paper to be submitted to *Wildlife Society Bulletin*

Brenna N. Towery[1] and Robert W. Klaver[2]

[1]Department of Natural Resource Ecology and Management, Iowa State University, Ames, IA 50011;

[2]U.S. Geological Survey, Iowa Cooperative Fish and Wildlife Research Unit, Ames, IA 50011

## Abstract

To provide state wildlife managers with a current assessment of giant Canada goose (*Branta canadensis maxima*) production in Iowa, we documented Canada goose nest survival at rural wetland sites in north-central Iowa. We monitored 121 nests in 2013 and 149 nests in 2014 at five Wildlife Management Areas (WMAs) with a variety of nesting sites, including islands, muskrat houses, and elevated nest structures. Daily nest survival rate (DSR) was estimated using the nest survival model in Program MARK which indicated that survival was influenced by year, site, stage, presence of a camera, nest age, and an interaction between nest age and stage. Nest survival rates, averaged over the 28 day nesting period for each site and year combination, ranged from 0.11 to 0.94. Nest survival was highest at sites with nest structures (beta estimate = 17.34). Our results provided support for the use of nest structures as a method for increasing Canada goose production in rural areas. Nest survival was negatively affected by lowered water levels at Rice Lake WMA (2013 beta estimate = -0.77, nest age beta estimate = -0.07). Timing of water level drawdowns for shallow lake restorations may influence nest survival rates.

**Keywords** *Branta canadensis maxima*, giant Canada goose, habitat, Iowa, nest survival, Program MARK, rural

## Introduction

The giant Canada goose (*Branta canadensis maxima*) was extirpated from most of its range in the early 1900s due to overharvest of the birds and their eggs (Bishop 1978, Hanson 1997), as well as habitat destruction through wetland drainage (Schrader 1955). Restoration efforts in Iowa were initiated in 1964 (Bishop and Howing 1972) by confining flocks of flightless geese to 15 wetland areas across the state (Zenner and LaGrange 1998a). These efforts were very successful and by the end of the century giant Canada geese (hereafter Canada geese) were nesting in every county in Iowa.

The first reintroduction sites were in north-central Iowa (Iowa DNR 2002), which lies within the southernmost portion of the Prairie Pothole Region (PPR). The PPR is characterized by shallow lakes and marshes that serve as highly productive waterfowl nesting habitat. The restored goose populations flourished and geese now nest there in high densities (Zenner and LaGrange 1998b). All reintroduction sites in Iowa were rural wetlands (Iowa DNR 2002) that provided ideal nesting habitats for Canada geese.

Multiple lakes and marshes in north-central Iowa contain islands that attract nesting Canada geese; muskrat activity on marshes produces additional nest sites, and the Iowa Dept. of Natural Resources (DNR) has erected nest structures for geese on some areas. Islands provide refuge from mammalian predators (Vermeer 1970, Giroux 1981), but can host limited numbers of geese due to their territorial behavior (Ewaschuk and Boag 1972). Muskrat houses and cattail mounds provide isolated nest sites generally safe from predators, but can be susceptible to flooding. Nest structures are highly secure nest sites, but require upkeep to remain usable.

A comprehensive Canada goose nest survival study has not been conducted in Iowa for over 30 years (Nigus 1979). The objective of this study was to determine how habitat and other factors influence Canada goose nest survival at rural wetlands in north-central Iowa, as well as to provide the Iowa DNR with updated estimates of Canada goose nest survival in various habitats. We also compared our nest survival estimates to those reported for Canada geese at other sites in the PPR.

## Study Area

We monitored Canada goose nests at Rice Lake Wildlife Management Area (WMA) and Big Wall Lake in 2013, and at Rice Lake WMA, Big Wall Lake WMA, East Twin Lake WMA, Union Hills Waterfowl Production Area (WPA) and Lower Morse WPA in 2014. The sites are located in Winnebago, Worth, Hancock, Cerro Gordo, and Wright counties in north-central Iowa (Figure 1). These counties lie within the southernmost portion of the PPR, which historically supported high densities of nesting Canada geese.

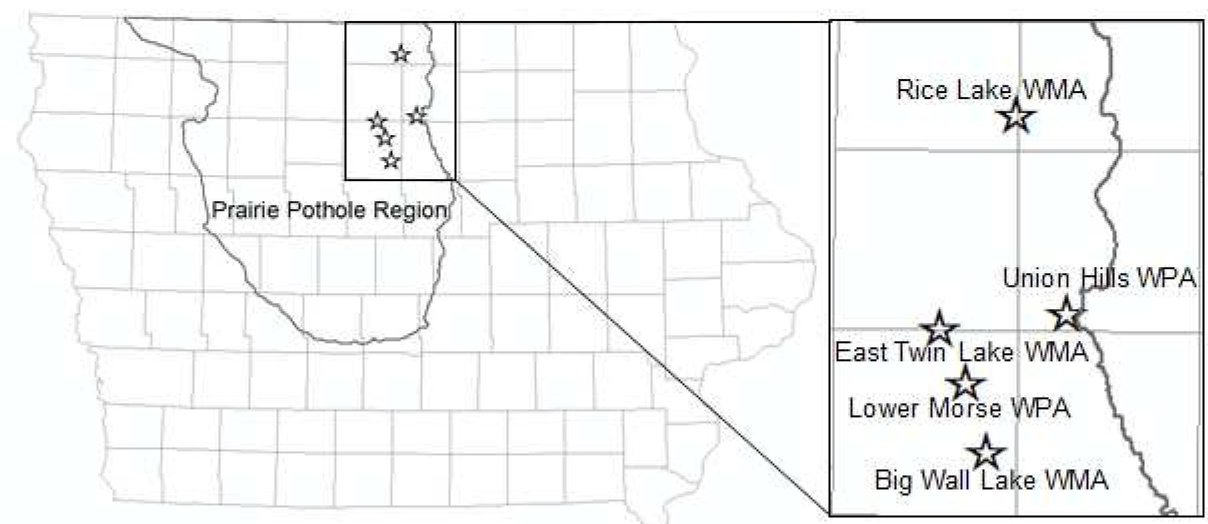



Figure 1. Map of rural wetland study sites in Winnebago, Worth, Wright, Cerro Gordo, and Hancock counties in north-central Iowa.

All sites were located outside of municipality boundaries and each provided a particular nesting habitat for geese. Rice Lake WMA consisted of Rice Lake and the adjacent Joice Slough. Rice Lake is a 409-ha, shallow, natural lake with a maximum depth of 3 m that contains 20 natural islands ranging in size from 0.04 to 3.9 ha. In April 2013, Rice Lake's water level was lowered 1 m by the Iowa DNR for the purpose of renovating the fish population, enhancing aquatic vegetative communities, and improving water quality. Due to this manipulation, not all islands were completely surrounded by water during the study. The water level was considerably lower late in the nesting period than it was early in the nesting period, and by June only four islands remained surrounded by water. The Joice Slough is a 73-ha marsh with a maximum depth of 1 m that contains 15 islands ranging in size from 0.02 to 3.19 ha and is separated from Rice Lake by a narrow road. The Joice Slough's water level was not manipulated by the Iowa DNR, but natural fluctuations resulted in only six islands surrounded by water during this study.

East Twin Lake (197 ha) and Big Wall Lake (363 ha) are shallow, natural lakes that contain dense stands of cattails (*Typha* species). Muskrats (*Ondatra zibethicus*) construct houses and feeding platforms from cattails, which provide elevated insular nest sites for Canada geese (Kiviat 1978). Union Hills (n = 19) and Lower Morse WPAs (n = 20) are wetland complexes where the Iowa DNR has installed similar numbers of nest structures for Canada geese. The structures at these sites were post structures that consist of a fiberglass tub or wire mesh basket attached to a 2–3 m steel pipe mounted over the water and filled with straw nesting material. We monitored nests at five discrete management areas, but because Rice Lake WMA included two separate wetlands our study consisted of six rural wetland sites.

## Methods

### Nest searches

We began nest searches at our selected sites on 6 April 2013 and 18 April 2014 and continued searches through late May. At Rice Lake WMA, all accessible islands were searched systematically. East Twin Lake and Big Wall Lake were explored via canoe. Nest structures at

Union Hills and Lower Morse were checked weekly, as were all other sites. Nests were located by flushing the incubating adult, by sighting a goose on a nest, or by searching muskrat houses for active nests. An effort was made to search the entire wetland, including areas that were difficult to access.

Upon locating a nest, we recorded its spatial coordinates in a GPS unit and assigned the nest a unique identification number. At Rice Lake WMA, we marked nests with a natural-colored, wooden tongue depressor due to high nest densities on islands. Markers were inconspicuous and were not expected to attract nest predators (Hammond and Forward 1956). Camera traps were placed at a sample of nests at Rice Lake WMA to identify the nest predators at these sites. Cameras were placed 1–2 m from the nest.

At all sites we recorded the number of eggs present in each nest and their developmental age (in days) to predict hatch date. The embryonic developmental age was determined using a field candling device. This method was most practical for field use and similar in accuracy to weighing or floating eggs (Weller 1956, Walter and Rusch 1997, Reiter and Anderson 2008). Egg handling procedures and other study methods were approved by the Iowa State University Institutional Animal Care and Use Committee (protocol #11–12–7460–Q).

Canada geese are often seen nesting in close proximity to each other, especially on islands (Klopman 1958, Ewaschuk and Boag 1972, Zenner and LaGrange 1998a). At high nest densities, territorial geese can exhibit aggression toward other nesting geese, potentially causing nest desertion (Naylor 1953). Ewaschuk and Boag (1972) reported that vegetation height surrounding a nest was inversely correlated to the frequency of territorial interactions with nearby nesting geese. To determine whether vegetation was related to nest survival, we took visual obstruction readings (VOR) using a Robel pole (Robel et al. 1970, Toledo et al. 2008) during the initial visit at ground nests. The Robel pole was placed just outside of the nest bowl and readings were taken from the four cardinal directions and averaged for each nest.

Nests were checked three times during the nesting period and once post-hatch to determine nest fate; nests terminated prior to hatch had fewer checks. Welch's *t*-test was conducted to compare initiation and hatch dates between years and sites. A nest was considered successful if at least one egg hatched (Mayfield 1961), and hatched eggs were identified by the presence of eggshell fragments and detached intact membranes in the nest (Girard 1939, Cooper 1978). Nests were considered depredated if any eggs appeared to have been eaten; they were considered abandoned if the eggs were cold and uncovered.

**Nest survival modeling**

When modeling nest survival, individual nest covariates typically produce more robust estimates of survival and can explain potential sources of variation in daily survival rates (Dinsmore et al. 2002). We included VOR mean and variance as covariates because we hypothesized that vegetation height could affect nest survival by decreasing intraspecific aggression. We also incorporated nest age as a covariate (Dinsmore et al. 2002) because we hypothesized that survival increased with age due to increased attentiveness of the incubating goose (Klett and Johnson 1982). Trail cameras were placed near some nests at Rice Lake WMA, so we included a covariate denoting the presence of a camera to determine if cameras had an effect on survival.

We developed models using the nest survival model in Program MARK to produce an estimate of daily survival rate (DSR; Dinsmore et al. 2002, White and Burnham 1999). Nest data were grouped by site, stage (egg laying and incubation), and year to account for potential variation in survival due to different habitat types at sites, behavioral differences during each stage, and annual variation in weather and site conditions, respectively. This resulted in a total of 15 groups and 4 nest-specific covariates. We developed models hierarchically by first testing group effects, then adding time effects to the best group model, and finally adding each covariate individually to the top model (Dinsmore and Dinsmore 2007). We hypothesized that groups with similar primary nesting habitats would have similar nest survival, so we started by comparing two models that tested the six wetland sites individually and that paired similar sites into three groups. In other words, nests at Rice Lake and the Joice Slough were combined into one group, those at Big Wall Lake and East Twin Lake into a second group, and Union Hills and Lower Morse WPAs into a third. Time effects tested whether daily survival varied with a nest's age or whether daily survival varied across the nesting season. Nest age effects may be due to behavioral changes in the incubating goose; and a day effect may be due to temporal variation within the season or other indirect effects. The quadratic of these effects were tested as well. Model fit was assessed using Akaike's Information Criterion (AIC; Akaike 1973). Models within two AIC of the top model were not considered competitive (Burnham and Anderson 2002) and parameters not included in the top model were considered uninformative (Arnold 2010). Nest survival was calculated by raising DSR to a power equal to the incubation period (28 days; Cooper 1978). The variance of the DSR can be calculated using the delta method, which is a technique developed for demographic parameters that have been transformed (Powell 2009).

## Results

We monitored 121 nests in 2013 and 149 nests in 2014 for a total of 270 Canada goose nests during the course of the study (Table 1). The mean initiation date across all sites was similar in 2013 (16 April) and 2014 (13 April) ($t_{259} = 1.09$, $p = 0.278$). The mean initiation date for nest structures in 2014 (7 April) was more than a week earlier than nests on islands or muskrat houses (16 April) in the same year ($t_{49} = -6.10$, $p < 0.0001$). The mean hatch date across all sites was 19 May in 2013 and 16 May in 2014 ($t_{91} = 2.10$, $p = 0.039$. The mean hatch date for nest structures in 2014 was 8 May compared to 18 May for nests at other sites in the same year ($t_{59} = -4.87$, $p < 0.0001$). All nest attempts were completed by 17 June in both years.

Table 1. Number of giant Canada goose (*Branta canadensis maxima*) nests monitored during the egg-laying and incubation stages at six study sites in north-central Iowa, 2013–2014.

| | Site | Egg-laying | Incubation |
|---|---|---|---|
| 2013 | Rice Lake | 31 | 50 |
| | Joice Slough | 13 | 22 |
| | Big Wall Lake | 1 | 28 |
| 2014 | Rice Lake | 8 | 26 |
| | Joice Slough | 9 | 41 |
| | Big Wall Lake | 2 | 24 |
| | East Twin Lake | 0 | 25 |
| | Union Hills | 0 | 14 |
| | Lower Morse | 0 | 12 |

Geese nested on 10 of the 20 islands at Rice Lake in 2013 and 3 islands in 2014. Geese nested on 7 of the 15 islands on the Joice Slough in 2013 and 6 islands in 2014. Camera traps at these sites revealed nests were destroyed by coyotes (*Canis latrans*), raccoons (*Procyon lotor*), American crows (*Corvus brachyrhynchos*), and, in two instances, local farm dogs (*Canis lupus familiaris*). In 2014, 16 (80%) of the 20 nest structures available at Lower Morse WPA were used by nesting geese and 12 (63%) of the 19 structures at Union Hills WPA were used by nesting geese.

The model with the lowest AIC (Table 2) indicated that nest survival was influenced by the year, site, stage, presence of a camera on the nest, age of the nest, and an interaction between nest age and stage (Table 3). The top model had 12 times more support than the next best model; VOR mean and variance were uninformative covariates.

There was no difference in support between the model that combined sites with similar nesting habitat and the model that kept the six sites separate, so we continued building models with similar sites combined, for the sake of simplicity. The most parsimonious model indicated that sites with nest structures (Union Hills and Lower Morse) had the highest daily survival rates during the nesting period; however, DSR was not statistically different among sites with muskrat houses and islands, as evidenced by the overlapping confidence intervals (Table 3). Other group effects indicated nest survival was lower in 2013 than in 2014 and lower during the egg-laying stage than during the incubation stage at Rice Lake and the Joice Slough (Table 4). Year and stage effects at other sites were not supported by the model.

Daily survival rates were influenced by the nest age and trail camera covariates, but only at Rice Lake and the Joice Slough. Cameras were only used at Rice Lake and Joice Slough and our model indicated that their presence did not have a negative impact on nest survival. Our results indicate that cameras had a positive effect on nest survival, but this is likely due to non-random placement of cameras on nests. The effect of nest age on daily survival rate was not significant for sites with nest structures and muskrat houses. Model results indicated daily survival declined with nest age at sites with islands (beta estimate = -0.078, 95% CL = -0.111, -0.046, Figure 2). Nest survival at Rice Lake and the Joice Slough declined from 0.36 to 0.0005 (mean = 0.11) in 2013 and from 0.69 to 0.05 (mean = 0.35) in 2014 during the 28-day incubation period. Nest survival ranged from 0.50 to 0.37 (mean = 0.44) at Big Wall Lake in 2013 and from 0.40 to 0.28 (mean = 0.34) at Big Wall Lake and East Twin Lake in 2014 during the 28-day incubation period. Nest survival ranged from 1.00 to 0.48 (mean = 0.94) at Union Hills and Lower Morse in 2014 during the 28-day incubation period.

Table 2. Models of daily survival rate for giant Canada goose nests monitored at rural wetlands in north-central Iowa, 2013–14. Models are listed in descending order by AIC weight. Models were created in Program MARK using 15 groups (3 sites for 2 years with 2 stages and 3 sites for 1 year and 1 stage) and the following covariates: mean and variance of visual obstruction readings using a Robel pole at the nest (VOR and VORvar), an effect of a nest's age (Age), a stage by age effect (Stage × Age), a linear and quadratic effect of day within the nesting season (Day and Day^2), and an effect of a camera on a nest (Cam). Sites with similar primary nesting habitats were grouped together, which condensed the number of site groups from 6 to 3.

| Model | ΔAIC* | $w_i$ | *K* | Deviance |
|---|---|---|---|---|
| Yr + Site(3) + Stage + Age + Stage × Age + Cam | 0.00 | 0.88 | 11 | 490.32 |
| Yr + Site(3) + Stage + Age + Stage × Age + VOR | 5.20 | 0.07 | 12 | 493.50 |
| Yr + Site(3) + Stage + Age + Stage × Age | 6.00 | 0.04 | 10 | 498.34 |
| Yr + Site(3) + Stage + Age + Stage × Age + VORvar | 8.68 | 0.01 | 12 | 496.99 |
| Yr + Site(3) + Stage + Age | 14.88 | 0.00 | 9 | 509.23 |
| Yr + Site(3) + Stage + Age^2 | 17.85 | 0.00 | 12 | 506.16 |
| Yr + Site(3) + Stage + Day | 27.73 | 0.00 | 9 | 522.07 |
| Yr + Site(3) + Stage | 27.85 | 0.00 | 6 | 528.23 |
| Yr + Site(3) + Stage + Day^2 | 27.96 | 0.00 | 12 | 516.26 |
| Yr + Site(3) | 64.63 | 0.00 | 5 | 567.01 |
| Site(6) | 78.40 | 0.00 | 6 | 580.78 |
| Site(3) | 78.72 | 0.00 | 3 | 585.11 |
| Constant survival | 96.36 | 0.00 | 1 | 606.76 |

*Best model had an AIC value of 522.86.
$w_i$ = model weight
*K* = number of parameters
Yr = 2013, 2014
Site(6) = Rice Lake, Joice Slough, Big Wall Lake, East Twin Lake, Union Hills, Lower Morse
Site(3) = grouped sites with similar primary nesting habitat (Rice Lake + Joice Slough, Big Wall Lake + East Twin Lake, and Union Hills + Lower Morse)
Stage = egg laying, incubation

Table 3. Intercept and slope estimates for a nest survival model comparing sites with similar nesting habitats in north-central Iowa, 2013–2014. Rice Lake (RL) and Joice Slough (JS) sites had islands, Big Wall Lake and East Twin Lake had muskrat houses, and Union Hills WPA and Lower Morse WPA had nest structures. The standard error (SE), lower 95% confidence limit (LCL) and upper 95% confidence limit (UCL) are also reported.

| Parameter | Estimate | SE | LCL | UCL |
|---|---|---|---|---|
| Intercept (RL & JS) | 3.190 | 0.101 | 2.991 | 3.389 |
| Union Hills & Lower Morse | 2.754 | 1.006 | 0.781 | 4.727 |
| Big Wall and East Twin | 0.216 | 0.207 | -0.189 | 0.622 |

Table 4. Intercept and slope estimates from the top model for the predicted daily survival rate of giant Canada goose nests at Rice Lake (RL), Joice Slough (JS), Big Wall Lake (BW), East Twin Lake (ET), Union Hills (UH) WPA, and Lower Morse (LM) WPA in north-central Iowa, 2013–2014. The standard error (SE), lower 95% confidence limit (LCL) and upper 95% confidence limit (UCL) are also reported. The best model included a group effect for sites with similar primary nesting habitats, a year effect, an effect of nesting stage, a linear effect for nest age, a stage by age effect, and an effect of a camera on a nest.

| Parameter | Estimate | SE | LCL | UCL |
|---|---|---|---|---|
| Intercept (RL + JS, 2014, incubation stage) | 5.397 | 0.433 | 4.548 | 6.246 |
| 2013 (RL + JS) | -0.768 | 0.230 | -1.219 | -0.317 |
| Egg-laying stage (RL + JS) | -3.649 | 0.525 | -4.678 | -2.620 |
| Age (RL + JS) | -0.078 | 0.017 | -0.111 | -0.046 |
| Egg-laying stage × Age (RL + JS) | 0.128 | 0.043 | 0.045 | 0.212 |
| Camera | 1.005 | 0.403 | 0.215 | 1.796 |
| Intercept (BW + ET, 2014) | 3.597 | 0.685 | 2.254 | 4.940 |
| 2013 (BW + ET) | 0.303 | 0.389 | -0.460 | 1.066 |
| Age (BW + ET) | -0.013 | 0.029 | -0.069 | 0.043 |
| Intercept (UH + LM, 2014) | 17.344 | 15.632 | -13.294 | 47.983 |
| Age (UH + LM) | -0.415 | 0.498 | -1.392 | 0.561 |

## Discussion

Our primary finding was that nest structures produced significantly higher nest survival than islands and muskrat houses, and manipulating the water level for lake renovation had a negative impact on nest survival at Rice Lake WMA. Nest structures are inherently secure nest sites. Many studies have reported high nest survival rates for elevated structures (Craighead and Stockstad 1961, Brakhage 1965, Cooper 1978, Nigus 1979, Kadlec and Smith 1992). Our results support these findings because we also found very high nest survival rates in structures (0.90). Muskrat houses and islands are less secure nest sites due to 1) increased exposure to predators, and 2) flooding caused by spring runoff (Klopman 1958, Cooper 1978, Giroux 1981).

Although nest structures produced high nest survival, not all structures at Union Hills and Lower Morse WPAs were used. Sertle and Eichholz (2006) reported zero use of nest structures by Canada geese and suggested that geese had not yet “learned” to use them because they had

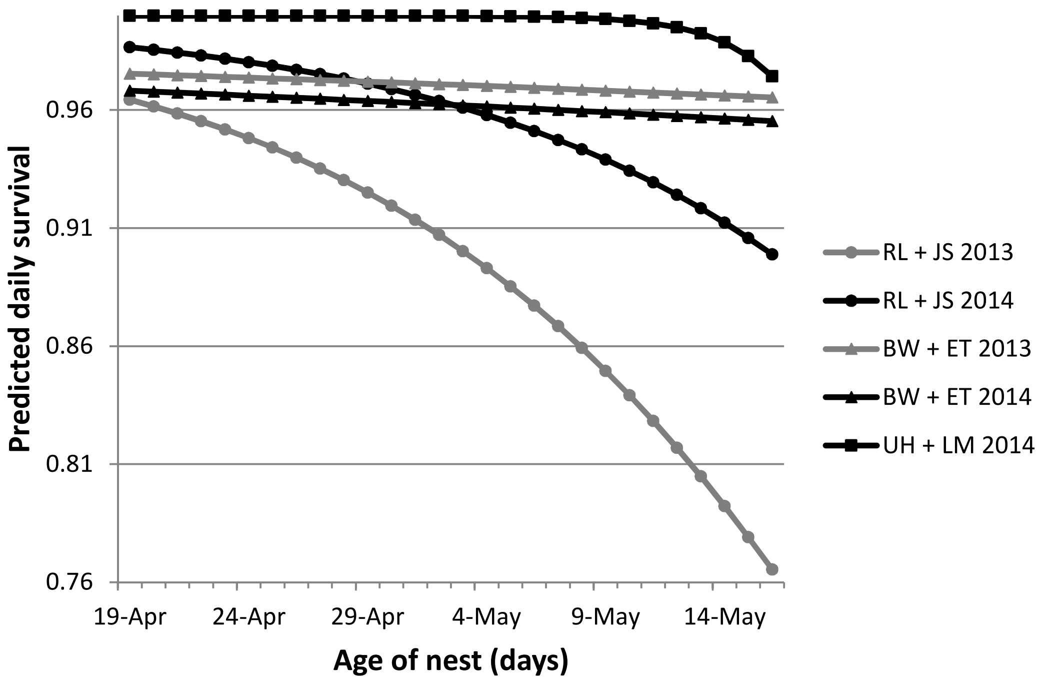



Figure 2. Predicted daily survival from the best model for giant Canada goose nests during the incubation stage at Rice Lake (RL), Joice Slough (JS), Big Wall Lake (BWL), East Twin Lake (ET), Union Hills (UH) WPA, and Lower Morse (LM) WPA in north-central Iowa, 2013–2014.

recently been installed. This could have been the case for geese nesting at Union Hills and Lower Morse WPAs. Nest structures, moreover, require annual maintenance and without this geese are less likely to use them for nesting (Ball 1990, Zenner at al. 1992). Proper placement and installation of the structure is essential, and a lack of nest material in the tub/basket or placement of the structure at a wetland with highly variable water levels could potentially deter a goose from nesting in a structure (Zenner et al. 1992). Advantages of structures are they are easy to install, inexpensive, and commercially available. Most importantly nest structures are valuable for goose production because they are nearly predator proof (Brakhage 1966, Zenner et al. 1992).

We found no statistical difference in nest survival at sites with muskrat houses versus islands, which suggests that either nesting habitat could be beneficial for Canada goose production. To maintain these habitat types for geese, water levels, muskrats, and vegetation must be managed (Ervin 2011). Providing nesting geese with muskrat houses requires a sufficient muskrat population, which is dependent on wetland habitat conditions and water levels. Consistently high water levels and absence of the natural wet-dry cycle will cause wetland habitats to degrade resulting in a decline in muskrat populations (McLeod 1950, Ervin 2011). Habitat management for muskrats involves water level manipulation (Erb and Perry 2003) which promotes nutrient cycling and regrowth of emergent vegetation which muskrats rely on for food and lodging (Weller and Frederickson 1973, Clark 2000). These management practices are currently being implemented by the Iowa DNR under the Shallow Lakes Initiative Project (Evelsizer and Fisher 2006), which has been beneficial for fish and wildlife populations, as well as for the general public. The project, however, has involved intensive and long-term monitoring and sampling efforts and annual water level manipulations (Iowa DNR 2013), all of which are necessary to maintain water quality and wetland health.

Sites with islands require maintenance as well, as evidenced by the condition of islands at Rice Lake and the Joice Slough. Basic requirements for nesting geese are open visibility and protection (Cooper 1978), which islands can provide if understory vegetation is adequately managed. Rice Lake and Joice Slough islands have become dominated by shrubs and trees, which have possibly impacted nest densities (Lokemoen and Messmer 1994, Towery 2015). Habitat management tools, such as clear cuts, herbicide spray, and controlled burns, can be used to regulate ecological succession on islands (Lokemoen and Messmer 1994). Habitat management can be costly and labor intensive, and potentially affect other species, but islands are a valuable resource to nesting geese (Giroux 1981). If increasing goose densities is desired, habitat management on islands would be necessary.

Although lowering water levels is important for emergent vegetation propagation, our results demonstrated that water level manipulations can negatively impact nest survival on islands if low water levels allow islands to become attached to the mainland. Nest survival at Rice Lake WMA was lower in 2013 than in 2014 and declined with nest age, likely due to the drastic fluctuation and manipulation of water levels in spring of 2013. Drought conditions in 2012 prompted the Iowa DNR to manually lower the water level at Rice Lake for renovation in April 2013 (Iowa DNR 2013), just when geese were beginning to nest. The unnaturally rapid decline in water level at Rice Lake (from 0.5 m below crest in April 2013 to 1.1 m below crest in May 2013) permitted terrestrial predators to access many islands after geese had begun nesting, resulting in a decline in nest survival. Our nest survival model results indicated that a nest's age had an effect on daily survival rates. The drastic change in habitat conditions throughout the nesting season suggests that perhaps the day within the season should have had more of an effect on DSR than the nest age, but these two effects can be difficult to separate unless all nest ages are represented across the entire nesting season. There is likely some confounding with these two parameters, but at least the nest age covariate is explaining some variation in the DSR. Regardless, it was apparent that the water level manipulation lowered nest survival. Adaptations in Canada goose nesting behavior and stable water level conditions resulted in an improvement in nest survival at Rice Lake WMA in 2014 (Towery 2015). Meeks (1969) demonstrated how timing of water level drawdowns impacted vegetation composition and productivity of spring-breeding wildlife. Modifications to the timing of future lake renovation activities in Iowa could improve Canada goose nest survival, assuming improving Canada goose production was a management goal for the lake.

Contrary to results reported by Ewaschuk and Boag (1972), we found that vegetation density surrounding goose nests had no effect on nest survival. Ewaschuk and Boag (1972) monitored nests on one large island, whereas Rice Lake WMA had 35 islands of varying sizes. The availability of more islands and subsequently more nest sites may have reduced aggressive interactions between nesting geese, nullifying the effect of vegetation density. On the other hand, VOR for some nests were taken prior to leaf-out which could have resulted in a misrepresentation of the vegetation density surrounding those nests later in incubation. Studies of other ground–nesting avian species have reported a positive correlation between vegetation structure and nest survival (Fondell and Ball 2004, Kolada et al. 2009, Kerns et al. 2010, Conover et al. 2011), primarily due to reduced predation. Canada geese, however, are large birds and have fewer predation risks than other ground-nesting avian species, particularly when nesting on islands.

One of the assumptions of nest survival analysis is that nest fates are independent (Bart and Robson 1982, Dinsmore et al. 2002). This assumption may have been violated for nests on islands at Rice Lake WMA, which could have resulted in an underestimate of the sampling variance (Flint et al. 1995, Dinsmore and Knopf 2005). No empirical test or goodness-of-fit procedure has been developed to deal with this particular dependence issue. Fortunately, survival estimates typically remain unbiased (Dinsmore and Knopf 2005).

Our mean nest survival estimates (0.11–0.94) for Canada geese nesting in north-central Iowa are comparable to other estimates of Canada geese nesting in the PPR. Although apparent estimates of nest success were calculated in early studies, Ewaschuk and Boag (1971) reported success rates ranging from 0.27 to 0.69 in Alberta during 1967–69, Cooper (1978) reported rates ranging from 0.39 to 0.43 in Manitoba during 1969–71, and Giroux (1982) reported a 0.70

success rate in southeast Alberta during 1976–78. Dieter and Anderson (2009) reported a 0.63 nest success rate in eastern South Dakota using the Mayfield method. Similar to this study, Dieter and Anderson (2009) found no difference in survival among ground nest habitat types.

Nigus (1979) monitored Canada goose nests at 13 sites in northwestern Iowa during 1977–78 at which 379 artificial nest structures had been erected by the Iowa DNR. Apparent nest success rates were high (0.69 and 0.82 in 1977 and 1978, respectively) due to the availability and use of the structures (Nigus 1979). Efforts by the Iowa DNR to erect structures during this time contributed to the successful restoration of Canada geese throughout the state (Zenner and LaGrange 1998a). Although islands are a preferred nest site for Canada geese (Kaminski and Prince 1977, Hanson 1997), our study provided evidence that islands do not reliably provide refuge from mammalian predators when water levels change rapidly during the nesting season or islands become exposed to land predators. Our results provided support that nest structures are highly valuable nesting habitats for geese, and that islands and muskrat houses produce similar nest survival rates for geese.

## Management Implications

According to the Iowa Canada Goose Management Plan (Iowa DNR 2002), the state was in need of information on Canada goose production to more effectively manage and monitor the population. This study provided an updated estimate of Canada goose nest survival in a variety of rural wetland types in Iowa's PPR. Nest survival data serves as a component of production, which contributes to overall knowledge of the population dynamics of Canada geese in Iowa. Our results provided support for the use of nest structures as a method for increasing Canada goose production in rural areas if the need arises, but decisions regarding goose production on WMAs will likely be influenced by the resources available to manage the habitat and what is best for other species, as well as members of the surrounding community. We also demonstrated that the timing of water level manipulations plays an important role in Canada goose production, particularly on islands.

## Acknowledgments

We thank P. Bartelt, P. Eyheralde, J. Godwin, S. Handrigan, O. Jones, K. Murphy, R. Reeves, and G. Zenner for their efforts in nest searching and monitoring, S. Dinsmore for guidance on statistical analysis, the Iowa DNR for providing field housing, and J. Morris for access to his Jon boat. Partial funding for this project was provided through the Iowa Department of Natural Resources Fish and Wildlife Trust Fund Contract CRWB0046–8340–WSUCH and Cooperative Agreement Number G12AC20381 from the United States Geological Survey. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

## Literature Cited

Akaike, H. 1973. Information theory as an extension of the maximum likelihood principle. Pages 267–281 *in* B. N. Petrov, and F. Csaki, editors. Second International Symposium on Information Theory. Akademiai Kiado, Budapest, Hungary.

Arnold T. W. 2010. Uninformative parameters and model selection using Akaike's Information Criterion. Journal of Wildlife Management 74:1175–1178.

Ball, I. J. 1990. 13.2.12 Artificial nest structures for Canada geese. Waterfowl Managament Handbook. Montana Cooperative Wildlife Research Unit, University of Montant, Missoula, Montana, USA.

Bart, J., and D. S. Robson. 1982. Estimating survivorship when the subjects are visited periodically. Ecology 63:1078–1090.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Springer, New York, New York, USA.

Bishop, R. A., and R. G. Howing. 1972. Re-establishment of the giant Canada goose in Iowa. Proceedings of the Iowa Academy of Science 79:14–16.

Bishop, R. A. 1978. Giant Canada geese in Iowa. Iowa Conservationist 37:5–12.

Brakhage, G. K. 1965. Biology and behavior of tub-nesting Canada geese. Journal of Wildlife Management 29:751–771.

Brakhage, G. K. 1966. Tub nests for Canada geese. Journal of Wildlife Management 30:851–853.

Clark, W. R. 2000. Ecology of muskrats in prairie wetlands. Pages 287–313 *in* H. R. Murkin, A. G. van der Valk, and W. R. Clark, editors. Prairie Wetland Ecology: the contribution of the Marsh Ecology Research Program. Iowa State Press, Ames.

Conover, R. R., S. J. Dinsmore, and L. W. Burger, Jr. 2011 Effects of conservation practices on bird nest density and survival in intensive agriculture. Agriculture, Ecosystems & Environment 141:126–132.

Cooper J. A. 1978. The history and breeding biology of the Canada Geese of Marshy Point, Manitoba. Wildlife Monographs No. 61:3–87.

Craighead, J. J., and D. S. Stockstad. 1961. Evaluating the use of aerial nesting platforms by Canada geese. Journal of Wildlife Management 25:363–372.

Dieter, C. D., and B. J. Anderson. 2009. Reproductive success and rbood movements of giant Canada geese in eastern South Dakota. American Midland Naturalist 162:373–381.

Dinsmore, S. J., G. C. White, and F. L. Knopf. 2002. Advanced techniques for modeling avian nest survival. Ecology 83:3476–3488.

Dinsmore S. J., and F. L. Knopf. 2005. Differential parental care by adult mountain plovers, *Charadrius montanus*. Canadian Field-Naturalist 119:532–536.

Dinsmore, S. J., and J. J. Dinsmore. 2007. Modeling avian nest survival in program MARK. Studies in Avian Ecology 34:73–83.

Erb, J. D., and H. R. Perry Jr. 2003. Muskrats (*Ondatra zibethicus* and *Neofiber alleni*) Pages 311–348 *in* Wild Mammals of North America, Second Edition. G. A. Feldhammer, B. C. Thompson, and J. A. Chapman, editors, Johns Hopkins University Press, Baltimore, Maryland, USA.

Ervin, M. 2011. Population characteristics and habitat of muskrats (*Ondatra zibethicus*) in the Summerberry Marsh Complex, The Pas, Manitoba, Canada. Master's Thesis, Iowa State University, Ames, Iowa, USA.

Evelsizer, V., and M. Fisher. 2006. Protocol for monitoring the ecological condition of shallow lakes before and after renovation. Iowa DNR, Watershed Monitoring and Assessment Section: Iowa City, IA.

Ewaschuk, E., and D. A. Boag. 1972. Factors affecting hatching success of densely nesting Canada geese. Journal of Wildlife Management 36:1097–1106.

Flint, P. L., K. H. Pollock, D. Thomas, and J. S. Sedinger. 1995. Estimating prefledgling survival: allowing for brood mixing and dependence among brood mates. Journal of Wildlife Management 59:448–455.

Fondell, T. F., and I. J. Ball. 2004. Density and success of bird nests relative to grazing in western Montana grasslands. Biological Conservation 117:203–213.

Girard, G. L. 1939. Life history of the shoveler. Transactions of the North American Wildlife Conference 4:364-371.

Giroux, J. F. 1981. Use of artificial islands by nesting waterfowl in southeastern Alberta. Journal of Wildlife Management 45:669–679.

Hammond, M. C., and W. R. Forward. 1956. Experiments on causes of duck nest predation. Journal of Wildlife Management 20:243–247.

Hanson, H. C. 1997. The Giant Canada Goose. Revised edition. Illinois Natural History Survey: Carbondale, Illlinois, USA.

Iowa Department of Natural Resources [Iowa DNR]. 2002. Iowa Canada Goose management plan. DNR State Wildlife Management Plan: Clear Lake, Iowa, USA.

Iowa Department of Natural Resources [Iowa DNR]. 2013. Rice Lake management plan. DNR Management Plan: Ventura, Iowa, USA.

Kadlec, J. A., and L. M. Smith. 1992. Habitat management for breeding areas. Pages 590–610 *in* B. D. J. Batt, A. D. Afton, M. G. Anderson, C. Dankney, D. H. Johnson, J. A. Kadlec, and G. L. Krapu, editors. Ecology and management of breeding waterfowl. University of Minnesota Press, Minneapolis, USA.

Kaminski, R. M., and H. H. Prince. 1977. Nesting Habitat of Canada Geese in Southeastern Michigan. Wilson Bulletin 89:523–531.

Kerns, C. K., M. R. Ryan, R. K. Murphy, F. R. Thompson, and C. S. Rubin. 2010. Factors affecting songbird nest survival in northern mixed-grass prairie. Journal of Wildlife Management 74:257–264.

Kiviat, E. 1978. Vertebrate use of muskrat lodges and burrows. Estuaries 1:196–200.

Klett, A. T., and D. H. Johnson. 1982. Variability in nest survival rates and implications to nesting studies. Auk 99:77–87.

Klopman, R. B. 1958. The nesting of the Canada Goose at Dog Lake, Manitoba. Wilson Bulletin 70:168–183.

Kolada, E. J., M. L. Casazza, and J. S. Sedinger. 2009. Ecological factors influencing nest survival of greater sage-grouse in Mono County, California. Journal of Wildlife Management 73:1341–1347.

Lokemoen, J. T., and T. A. Messmer. 1994. Locating, constructing, and managing islands for nesting waterfowl. U.S. Fish and Wildlife Service, Branch of Extension and Publications, Arlington, VA and The Berryman Institute, Logan, UT. Jamestown, ND: Northern Prairie Wildlife Research Center Online. Available from http://www.npwrc.usgs.gov/resource/birds/island/index.htm (accessed March 2015).

Mayfield, H. F. 1961. Nesting success calculated from exposure. Wilson Bulletin 73:255–261.

McLeod, J. A. 1948. Preliminary studies of muskrat biology in Manitoba. Transactions of the Royal Society of Canada Vol. XLII: Series III: Section 5.

Meeks, R. L. 1969. The effect of drawdown date on wetland plant succession. Journal of Wildlife Management 33:817–821.

Naylor, A. E. 1953. Production of the Canada goose on Honey Lake Refuge, Lassen County, California. California Fish and Game 3983–3994.

Nigus, T. A. 1979. Productivity and nest site selection of Canada geese in northwestern Iowa. Thesis, Iowa State University, Ames, Iowa, USA.

Powell, L. A. 2009. Approximating variance of demographic parameters using the delta method: a reference for avian biologists. Condor 109:949–954.

Reiter, M. E., and D. E. Andersen. 2008. Comparison of the egg flotation and egg candling techniques for estimating incubation day of Canada Goose nests. Journal of Field Ornithology 79:429–437.

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295–297.

Schrader, T. A. 1955. Waterfowl and the potholes of the north central states *in* The yearbook of agriculture 1955: Washington, D.C., U.S. Department of Agriculture, 84th Congress, 1st Session, House Document no. 32:596–604.

Sertle, M., and M. W. Eichholz. 2006. Nest success of giant Canada geese in southern Illinois. Transactions of the Illinois State Academy of Science 99:161–168.

Toledo, D„ L. B. Abbott, and J. E. Herrick. 2008. Cover pole design for easy transport, assembly, and field use. Journal of Wildlife Management 72:564–567.

Towery, B. N. 2015. The distribution and nest survival of Giant Canada Geese breeding in Iowa. Master's Thesis, Iowa State University, Ames, Iowa, USA.

Vermeer, K. 1970. A study of Canada Geese, *Branta canadensis*, nesting on islands in southeastern Alberta. Canadian Journal of Zoology 48:235–240.

Walter, S. E., and D. H. Rusch. 1997. Accuracy of egg flotation in determining age of Canada Goose nests. Wildlife Society Bulletin 25:854–857.

Weller, M. W. 1956. A simple field candler for waterfowl eggs. Journal of Wildlife Management 20:111–113.

Weller, M. W., and L. H. Fredrickson. 1973. Avian ecology of a managed glacial marsh. Living Bird 12:269–291.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46 Supplement:120–138.

Zenner, G. G., T. G. LaGrange, and A. W. Hancock. 1992. Nest structures for ducks and geese. Iowa Department of Natural Resources, Des Moines, IA.  Jamestown, ND: Northern Prairie Wildlife Research Center Online. <http://www.npwrc.usgs.gov/resource/birds/neststru/index.htm> Accessed 26 Feb 2015.

Zenner, G. G., and T. G. LaGrange. 1998a. Giant Canada geese in Iowa: restoration, management, and distribution. Pages 303-309 in D. H. Rusch, M. D. Samuel, D. D. Humburg, and B. D. Sullivan, eds. Biology and management of Canada geese. Proceedings of the International Canada Goose Symposium, Milwaukee, Wisconsin, USA.

Zenner, G. G. and T. G. LaGrange. 1998b. Densities and fates of Canada goose nests on islands in north-central Iowa. Pages 53-59 in D. H. Rusch, M. D. Samuel, D. D. Humburg, and B. D. Sullivan, eds. Biology and management of Canada geese. Proceedings of the International Canada Goose Symposium, Milwaukee, Wisconsin, USA.

# CHAPTER 5. GENERAL CONCLUSIONS

## Summary

Successful restoration and management efforts by the state's biologists and wildlife managers have produced a stable and productive giant Canada goose (*Branta canadensis maxima*) population in Iowa. Efforts to restore the giant Canada goose (hereafter Canada goose) population have been successful throughout the Mississippi Flyway (USFWS 2013). States and provinces within the Mississippi Flyway are continually looking to improve management and monitoring protocols (Leafloor et al. 2004). Our study contributed to these efforts by 1) providing statistically valid methods for predicting breeding pair densities to better stratify sections for the breeding population survey, 2) comparing Canada goose nesting activity on islands at one of Iowa's original restoration sites to a study conducted 25 years earlier, and 3) investigating how available nesting habitat and other factors influenced Canada goose nest survival at rural wetlands in north-central Iowa.

We developed a model to predict Canada goose breeding pair densities by incorporating National Wetlands Inventory data and previous breeding population survey data. Our study found that breeding pair densities were best predicted by the wetland types, number of wetlands, area of each wetland type, and a quadratic of the area of each wetland type in each section, as well as an interaction between the wetland types and the area of each wetland type, and random effects for observations and sections. Predictions were conservative and will require field corrections by biologists familiar with each county before being implemented into the breeding population survey. Our re-stratification, however, has provided a statistically valid stratification process which will improve precision of the breeding population estimates, as well as improve the efficiency of conducting the survey by reducing the necessary sample size. The methodology we've described is applicable to all Mississippi Flyway states and provinces which could improve Canada goose management in the Flyway as a whole.

While serving as a holding site for one of Iowa's original Canada goose restoration flocks, Rice Lake Wildlife Management Area (WMA) provided islands, nest structures, and muskrat houses as potential nest sites. After 25 years, we found that nesting habitat conditions had changed dramatically; nest structures and muskrat houses were no longer available and many islands had become densely vegetated with brush and trees. Our study concluded that the decline in available nest sites and succession on islands had resulted in lower nest densities on islands and seemingly fewer nesting geese overall. With that said, nest success was not significantly lower than rates reported by Zenner and LaGrange (1998). This was surprising considering the lake renovation initiated at Rice Lake in 2013 (Iowa DNR 2013) exposed many islands to increased predator activity resulting in high nest depredation rates. The availability of islands on the adjacent slough may have maintained nest success, but we concluded that reduced rates could have been avoided by lowering water levels after the waterfowl nesting season was complete. Since the Canada goose population has stabilized (Iowa DNR 2014) increasing production is not currently a concern. Should the state need to accommodate more nesting geese, however, habitat management on islands may improve nest densities at Rice Lake WMA.

In our analysis of Canada goose nest survival at five WMAs, we found that nest structures produced significantly higher nest survival than nests on islands and muskrat houses, and manipulating the water level for lake renovation had a negative impact on nest survival at Rice Lake WMA. Although islands are a preferred nest site for Canada geese (Kaminski and Prince 1977, Hanson 1997), our study provided evidence that islands do not reliably provide refuge from mammalian predators when water levels are lowered enough to allow islands to become connected to the mainland. Our results provided support for the use of nest structures as a method for increasing Canada goose production in rural areas if the need arises (Craighead and Stockstad 1961, Brakhage 1965, Cooper 1978, Nigus 1979, Kadlec and Smith 1992). However, decisions regarding goose production on WMAs will likely be influenced by the resources available to manage the habitat and what is best for other species, as well as residents of the nearby community. We also demonstrated that the timing of water level manipulations plays an important role in Canada goose production, particularly on islands.

Our estimates of nest survival at Rice Lake WMA during 2013–14 using apparent estimation methods (2013 = 0.27, 2014 = 0.38) were similar to the estimates produced by the nest survival model in Program MARK (White and Burnham 1999; 2013 = 0.11, 2014 = 0.35). This provides support for Johnson and Shaffer's (1990) argument that an apparent estimator of nest success is reliable for island nesting species. Detectability was high enough during our study for an accurate measure of nest success. Nests found depredated or abandoned during searches were incorporated into the total number of initiated nests for the apparent estimate because excluding them biases the estimate high due to the fact that nests found later in incubation are more likely to hatch (Mayfield 1961).

The Mississippi Flyway Council is looking to simplify Canada goose management by combining all populations into a unified management plan, which could involve big changes to current population monitoring protocols (Miss. Flyway Counc. Tech. Sect. Minutes, Little Rock, Ark., 23 February 2015, unpublished report). Until then, state and provincial breeding population surveys are a necessary tool to monitor population trends. Our research has provided a method of classifying wetland habitat for Mississippi Flyway states and provinces which will allow them to conduct the breeding population survey more efficiently and in a more statistically valid manner.

Canada goose management also involves managing habitat and we have provided information on how habitat characteristics have changed at Rice Lake WMA and the role various nesting habitats play in Canada goose nest survival. Future research should investigate how changes to the Mississippi Flyway Canada goose management plan will impact monitoring programs and survey methodology.

## Literature Cited

Brakhage, G. K. 1965. Biology and behavior of tub-nesting Canada geese. Journal of Wildlife Management 29:751–771.

Cooper, J. A. 1978. The history and breeding biology of the Canada Geese of Marshy Point, Manitoba. Wildlife Monographs No. 61:3–87.

Craighead, J. J., and D. S. Stockstad. 1961. Evaluating the use of aerial nesting platforms by Canada geese. Journal of Wildlife Management 25:363–372.

Hanson, H. C. 1997. The giant Canada goose. Revised edition. Southern Illinois Univ. Press, Carbondale, IL.

[Iowa DNR] Iowa Department of Natural Resources. 2013. Rice Lake management plan. DNR Management Plan: Ventura, Iowa, USA.

[Iowa DNR] Iowa Department of Natural Resources. 2014. Trends in Iowa wildlife populations and harvest - 2013. DNR Logbook: Boone, IA.

Johnson, D. H., and T. L. Shaffer. 1990. Estimating nest success: when Mayfield wins. Auk 107:595–600.

Kadlec, J. A., and L. M. Smith. 1992. Habitat management for breeding areas. Pages 590–610 *in* B. D. J. Batt, A. D. Afton, M. G. Anderson, C. Dankney, D. H. Johnson, J. A. Kadlec, and G. L. Krapu, editors. Ecology and management of breeding waterfowl. University of Minnesota Press, Minneapolis, USA.

Kaminski, R. M., and H. H. Prince. 1977. Nesting Habitat of Canada Geese in Southeastern Michigan. Wilson Bulletin 89:523–531.

Leafloor, J.O., K. F. Abraham, F. D. Caswell, K. E. Gamble, R. N. Helm, D. D. Humburg, J. S. Lawrence, D. R. Luukkonen, R. D. Pritchert, E. L. Warr, G. G. Zenner. 2004. Canada goose management in the Mississippi Flyway. Pages 22–36 *in* T. J. Moser, R. D. Lien, K. C. Vercauteren, K. F. Abraham, D. E. Andersen, J. G. Bruggink, J. M. Coluccy, D. A. Graber, J. O. Leafloor, D. R. Luukkonen, R. E. Trost, editors. Proceedings of the 2003 International Canada Goose Symposium, 19–21 March 2003, Madison, Wisconsin, USA.

Mayfield, H. F. 1961. Nesting success calculated from exposure. Wilson Bulletin 73:255–261.

Nigus, T. A. 1979. Productivity and nest site selection of Canada geese in northwestern Iowa. Thesis, Iowa State University, Ames, Iowa, USA.

[USFWS] U.S. Fish and Wildlife Service. 2013. Waterfowl population status, 2013. U.S. Department of the Interior, Washington, D.C. USA.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46 Supplement:120–138.

Zenner, G. G. and T. G. LaGrange. 1998. Densities and fates of Canada goose nests on islands in north-central Iowa. Pages 53-59 in D. H. Rusch, M. D. Samuel, D. D. Humburg, and B. D. Sullivan, eds. Biology and management of Canada geese. Proceedings of the International Canada Goose Symposium, Milwaukee, Wisconsin, USA.

# APPENDIX A. SURVEY DATA EXCERPT

| ID | STR_Type | Wetland_no | Type | Area_Type | County | STR | Area_Total | Years | Count |
|---|---|---|---|---|---|---|---|---|---|
| 0 | S17T85NR33W - Marsh - Seasonal | 9 | Marsh - Seasonal | 15352.38 | CARROLL | S17T85NR33W | 355606.2 | 5 | 0 |
| 0 | S17T85NR33W - Marsh - SemiPerm | 12 | Marsh - SemiPerm | 72319.5 | CARROLL | S17T85NR33W | 355606.2 | 5 | 0 |
| 0 | S17T85NR33W - Marsh - Temp | 4 | Marsh - Temp | 12346.66 | CARROLL | S17T85NR33W | 355606.2 | 5 | 0 |
| 0 | S17T85NR33W - River | 1 | River | 75047.07 | CARROLL | S17T85NR33W | 355606.2 | 5 | 3 |
| 1 | S10T71NR29W - Marsh - SemiPerm | 15 | Marsh - SemiPerm | 44454.31 | UNION | S10T71NR29W | 48416.24 | 5 | 8 |
| 1 | S10T71NR29W - Marsh - Temp | 3 | Marsh - Temp | 3961.929 | UNION | S10T71NR29W | 48416.24 | 5 | 0 |
| 2 | S10T82NR26W - Marsh - Seasonal | 4 | Marsh - Seasonal | 28314.83 | BOONE | S10T82NR26W | 890809.3 | 5 | 0 |
| 2 | S10T82NR26W - Marsh - SemiPerm | 1 | Marsh - SemiPerm | 6380.987 | BOONE | S10T82NR26W | 890809.3 | 5 | 2 |
| 2 | S10T82NR26W - Marsh - Temp | 5 | Marsh - Temp | 565948.9 | BOONE | S10T82NR26W | 890809.3 | 5 | 2 |
| 2 | S10T82NR26W - River | 1 | River | 290164.6 | BOONE | S10T82NR26W | 890809.3 | 5 | 2 |
| 3 | S10T83NR44W - Marsh - SemiPerm | 2 | Marsh - SemiPerm | 2562.298 | MONONA | S10T83NR44W | 133693.7 | 5 | 0 |
| 3 | S10T83NR44W - Marsh - Temp | 1 | Marsh - Temp | 38744.11 | MONONA | S10T83NR44W | 133693.7 | 5 | 0 |
| 3 | S10T83NR44W - River | 1 | River | 92387.34 | MONONA | S10T83NR44W | 133693.7 | 5 | 9 |
| 4 | S10T87NR27W - Marsh - Seasonal | 1 | Marsh - Seasonal | 1403.03 | WEBSTER | S10T87NR27W | 35137.5 | 3 | 0 |
| 4 | S10T87NR27W - Marsh - SemiPerm | 1 | Marsh - SemiPerm | 1449.163 | WEBSTER | S10T87NR27W | 35137.5 | 3 | 0 |
| 4 | S10T87NR27W - Quarry | 3 | Marsh - Temp | 5810.294 | WEBSTER | S10T87NR27W | 35137.5 | 3 | 0 |
| 4 | S10T87NR27W - Marsh - Temp | 2 | Quarry | 3960.38 | WEBSTER | S10T87NR27W | 35137.5 | 3 | 3 |
| 4 | S10T87NR27W - River | 2 | River | 22514.64 | WEBSTER | S10T87NR27W | 35137.5 | 3 | 0 |
| 5 | S10T90NR14W - Marsh - Seasonal | 11 | Marsh - Seasonal | 155008.4 | BLACK HAWK | S10T90NR14W | 526891.3 | 5 | 8 |
| 5 | S10T90NR14W - Marsh - SemiPerm | 8 | Marsh - SemiPerm | 14786.44 | BLACK HAWK | S10T90NR14W | 526891.3 | 5 | 10 |
| 5 | S10T90NR14W - Marsh - Temp | 6 | Marsh - Temp | 72907.46 | BLACK HAWK | S10T90NR14W | 526891.3 | 5 | 0 |
| 5 | S10T90NR14W - River | 3 | River | 284189 | BLACK HAWK | S10T90NR14W | 526891.3 | 5 | 20 |
| 6 | S10T96NR29W - Marsh - Seasonal | 3 | Marsh - Seasonal | 38038.88 | KOSSUTH | S10T96NR29W | 82803.74 | 5 | 0 |
| 6 | S10T96NR29W - Marsh - Temp | 3 | Marsh - Temp | 9260.377 | KOSSUTH | S10T96NR29W | 82803.74 | 5 | 0 |
| 6 | S10T96NR29W - River | 4 | River | 35504.49 | KOSSUTH | S10T96NR29W | 82803.74 | 5 | 1 |
| 7 | S10T97NR23W - Marsh - Seasonal | 6 | Marsh - Seasonal | 63844.51 | HANCOCK | S10T97NR23W | 117820.5 | 5 | 4 |
| 7 | S10T97NR23W - Marsh - SemiPerm | 6 | Marsh - SemiPerm | 39797.5 | HANCOCK | S10T97NR23W | 117820.5 | 5 | 18 |
| 7 | S10T97NR23W - Marsh - Temp | 4 | Marsh - Temp | 14178.45 | HANCOCK | S10T97NR23W | 117820.5 | 5 | 0 |

## APPENDIX B. R CODE SCRIPT FOR CANADA GOOSE BREEDING PAIR PREDICTIVE MODEL

```
library(lme4)
library(lmerTest)
library(neldermead)
setwd("C:\\\Users\\\btowery\\\Documents ")

survey <- read.csv("Surveyed_Model_Data.csv", header=T)
survey$logYears <- log(survey$Years)
survey$obs <- 1:length(survey$logYears)
str(survey)

survey.glmer2 <- glmer(Count ~ Wetland_no + Area.mil + Type +
                       Area.mil*Type + I(Area.mil^2) +
                       offset(logYears) + (1|STR) + (1|obs),
                       data = survey, family=poisson)

AIC(survey.glmer2)

#model validation
plot(survey.glmer2)
qqnorm(residuals(survey.glmer2))
plot(fitted(survey.glmer2), resid(survey.glmer2))

tmp<-resid(survey.glmer2)
hist(tmp, xlab="Residuals")

overdisp_fun <- function(model) {
  # number of variance parameters in an n-by-n variance-covariance matrix
  vpars <- function(m) { nrow(m)*(nrow(m)+1)/2}
  model.df <- sum(sapply(VarCorr(model),vpars))+length(fixef(model))
  rdf <- nrow(model.frame(model))-model.df
  rp <- residuals(model,type="pearson")
  Pearson.chisq <- sum(rp^2)
  prat <- Pearson.chisq/rdf
  pval <- pchisq(Pearson.chisq, df=rdf, lower.tail=FALSE)
  c(chisq=Pearson.chisq,ratio=prat,rdf=rdf,p=pval)}
overdisp_fun(survey.glmer2)

#model prediction using survey.glmer2 model
alldata = read.csv("All_Iowa_Model_Data.csv", header=TRUE)
alldata$obs = 1:length(alldata$STR)
head(alldata)
str(alldata)
```

```
Pred_Pairs <- predict(survey.glmer2, newdata = alldata, type = "response", allow.new.levels =
TRUE)

length(Pred_Pairs)
length(alldata$STR)

aaa <- cbind(alldata, Pred_Pairs)

str(aaa)

write.csv(aaa, "predicted.csv")
```